# NAVAL POSTGRADUATE SCHOOL
# Monterey, California

# THESIS

**APPLICATION OF THE JANUS COMBAT MODEL FOR ANALYSIS OF ALTERNATIVES: A STUDY OF THE OPERATIONAL EFFECTIVENESS OF THE COMMON MISSILE AS COMPARED TO THE HELLFIRE**

by

John M. Vannoy

June 2002

| | |
|---|---|
| Thesis Advisor: | Bard K. Mansager |
| Second Reader: | Scott T. Crino |
| Associate Advisor: | Keith Snider |

THIS PAGE INTENTIONALLY LEFT BLANK

| **REPORT DOCUMENTATION PAGE** | | | *Form Approved OMB No. 0704-0188* |
|---|---|---|---|
| Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503. | | | |
| **1. AGENCY USE ONLY *(Leave blank)*** | **2. REPORT DATE** June 2002 | **3. REPORT TYPE AND DATES COVERED** Master's Thesis | |
| **4. TITLE AND SUBTITLE** Application of the Janus Combat Model for Analysis of Alternatives: A Study of the Operational Effectiveness of the Common Missile as Compared to the Hellfire | | | **5. FUNDING NUMBERS** |
| **6. AUTHOR (S)** John M. Vannoy | | | |
| **7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)** Naval Postgraduate School Monterey, CA 93943-5000 | | | **8. PERFORMING ORGANIZATION REPORT NUMBER** |
| **9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)** N/A | | | **10. SPONSORING/MONITORING AGENCY REPORT NUMBER** |
| **11. SUPPLEMENTARY NOTES** The views expressed in this thesis are those of the author and do not reflect the official policy or position of the U.S. Department of Defense or the U.S. Government. | | | |
| **12a. DISTRIBUTION / AVAILABILITY STATEMENT** Approved for public release; distribution is unlimited | | | **12b. DISTRIBUTION CODE** |

**13. ABSTRACT *(maximum 200 words)***

By 2010, 100 percent of the existing stockpile of Hellfire and TOW 2A/2B missiles will reach their design shelf life. The stock of Hellfire missiles available to support Army air-to-ground combat will be depleted by 2015. Of particular interest to the Aviation community is the Comanche first unit equipped (FUE) in 2009, which will be significantly impacted by the scarcity and condition of this primary weapon. This research employs the Janus Combat Model in a Simulation Based Acquisition (SBA) approach to an Analysis of Alternatives (AOA) in an effort to find a replacement for these legacy missiles. Janus will be utilized to analyze the military worth of a newly proposed missile named the Common Missile (CM) as compared to its primary aviation employed alternative the Hellfire Missile (HF). This analysis utilizes an Army Aviation Deep Attack scenario developed within the Janus Combat Model for this evaluation. The objective of this research is to investigate which missile is the best operational alternative for Army Aviation and to determine to what extent it is better. For this research operational effectiveness will be evaluated statistically by analyzing the systems contribution to platform key measures of effectiveness such as lethality, survivability, and engagement. Additionally, an operational analysis is performed from the warfighter's perspective examining resource requirements and fundamental tactical employment differences between the CM and HF.

| **14. SUBJECT TERMS** | | | **15. NUMBER OF PAGES** |
|---|---|---|---|
| Analysis of Alternatives, Janus, Modeling and Simulation, Simulation Based Acquisitions, Army Attack Aviation, Longbow Apache, Common Missile, Hellfire Missile | | | 126 |
| | | | **16. PRICE CODE** |
| **17. SECURITY CLASSIFICATION OF REPORT** | **18. SECURITY CLASSIFICATION OF THIS PAGE** | **19. SECURITY CLASSIFICATION OF ABSTRACT** | **20. LIMITATION OF ABSTRACT** |
| Unclassified | Unclassified | Unclassified | UL |

**NSN 7540-01-280-5500** **Standard Form 298 (Rev. 2-89) Prescribed by ANSI Std. 239-18**

THIS PAGE INTENTIONALLY LEFT BLANK

**Approved for public release; distribution is unlimited**

# APPLICATION OF THE JANUS COMBAT MODEL FOR ANALYSIS OF ALTERNATIVES: A STUDY OF THE OPERATIONAL EFFECTIVENESS OF THE COMMON MISSILE AS COMPARED TO THE HELLFIRE


John M. Vannoy
Major, United States Army
B.S., Central Missouri State University, 1991


Submitted in partial fulfillment of the
requirements for the degree of

**MASTER OF SCIENCE IN MANAGEMENT**

from the

**NAVAL POSTGRADUATE SCHOOL**
**June 2002**

Author: John M. Vannoy

Approved by: Bard K. Mansager
Thesis Advisor

Scott T. Crino
Second Reader

Keith Snider
Associate Advisor

Douglas A. Brook
Dean, Graduate School of Business and Public Policy

THIS PAGE INTENTIONALLY LEFT BLANK

# ABSTRACT

By 2010, 100 percent of the existing stockpile of Hellfire and TOW 2A/2B missiles will reach their design shelf life. The stock of Hellfire missiles available to support Army air-to-ground combat will be depleted by 2015. Of particular interest to the Aviation community is the Comanche first unit equipped (FUE) in 2009, which will be significantly impacted by the scarcity and condition of this primary weapon. This research employs the Janus Combat Model in a Simulation Based Acquisition (SBA) approach to an Analysis of Alternatives (AOA) in an effort to find a replacement for these legacy missiles. Janus will be utilized to analyze the military worth of a newly proposed missile named the Common Missile (CM) as compared to its primary aviation employed alternative, the Hellfire Missile (HF). This analysis utilizes an Army Aviation Deep Attack scenario developed within the Janus Combat Model for this evaluation. The objective of this research is to investigate which missile is the best operational alternative for Army Aviation and to determine to what extent it is better. For this research operational effectiveness will be evaluated statistically by analyzing the systems' contributions to platform key measures of effectiveness such as lethality, survivability, and engagement. Additionally, an operational analysis is performed from the warfighter's perspective examining resource requirements and fundamental tactical employment differences between the CM and HF.

THIS PAGE INTENTIONALLY LEFT BLANK

# TABLE OF CONTENTS

# LIST OF FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK

# LIST OF TABLES

THIS PAGE INTENTIONALLY LEFT BLANK

ACKNOWLEDGEMENTS

I would like to extend my sincerest thanks to Scot Eisenhard and Robert Perry, without whom this thesis would not be possible. I am especially grateful to my wife, Amy, for her part in preparing this thesis. Additionally, a special thanks goes to my friend and thesis second reader, CPT(P) Scott Crino, for his patience, constructive recommendations and assistance.

THIS PAGE INTENTIONALLY LEFT BLANK

# I. INTRODUCTION

A study was accomplished at the direction of the Chief of Staff of the Army (CSA), which culminated with the identification of a mission need for a common missile that could replace current aging ground and air missiles. Two primary field conditions have driven the need for a new missile. These are an insufficient number of tube launched, optically tracked, wire-command link (TOW) guided missile weapons and Hellfire missiles in existing stockpiles to meet Commander in Chief (CINC) war fighting requirements and the overall age of the missile inventory. The stock of TOW missiles available to support ground combat will be depleted by the year 2012. By 2010, 100 percent of the existing stockpile of Hellfire and TOW 2A/2B missiles will reach their design shelf life. The stock of Hellfire missiles available to support Army air-to-ground combat will be depleted by 2015. Of particular interest to the Aviation community is the Comanche first unit equipped (FUE) in 2009, which will be significantly impacted by the scarcity and condition of this primary weapon. Moreover, ground units will be significantly impacted by the lack of an advanced missile system to support the Army's Transformation process and its cornerstone systems such as the Interim Armored Vehicle (IAV) and the Future Combat System (FCS). The IAV is scheduled for FUE in 2003, followed by FCS Milestone C (MS C) in 2010. These facts are the initial conditions that lay the groundwork for a valid and critical need for a common missile system. [Ref. 3]

Another key and driving factor is congressional concern directed at the many variants of Anti-Tank Guided Missiles (ATGM) being developed or maintained by each of the Services. This concern was recognized by the CSA and was an additional factor influencing his decision to pursue a top down approach to defining the mission need for a common missile system. The interests of Congress and the importance of fully exploring this concept are highlighted by these comments:

> The Committee questions the need to procure so many tank killing systems in a period in which our potential adversaries possess significantly smaller tank forces…The Committee believes the Office of the Secretary of Defense and the Joint Staff must do a better job in reviewing these programs to preserve resources for other priorities. (A statement from a hearing with the House Armed Services Committee.)[Ref. 3]

> The Committee understands that the Army is considering moving toward a "common" chemical energy missile in the future and that Modernized Hellfire is intended to be the baseline program to achieve this worthy goal. The Army is encouraged to provide a "Common Missiles" program funding line in the next budget submission." (A statement from the Senate Armed Services Committee regarding CM.) [Ref. 3]

A final statement by the House Authorization Committee ties the legislative branch's position together on CM:

> The conferees fully support the Army's goal to reduce the different types of anti-tank missile systems in its future tactical inventory… Furthermore, the conferees expect the Army to begin funding this effort in the fiscal year 2002 budget submission. [Ref. 3]

A critical program objective is to develop the CM to support multiple ground and air platforms. [Ref. 4] This

includes being backward compatible with existing Hellfire and TOW platforms. CM has been identified as the Comanche's principal missile and is critical to the program due to its need to reduce weight on the aircraft, while improving lethality and range. The program is also working to be available to support the initial deployment of the FCS. The program's objectives in the logistics area center on reduced deployment burden by creating a missile that supports the force in total. This effort is also focused on reducing Total Ownership Cost (TOC) through the reduction of unit level maintenance required and by modularizing the components, which will be common to all Services utilizing the CM as their primary ATGM. This fact points the program in a joint direction, which also includes key allied nations such as Great Britain.

The program office was established in October 2001 and is fully staffed as an Acquisition Category (ACAT) 1D project. The program has been horizontally integrated with the existing Hellfire program, which allows the CM office to benefit from funding lines established for the Hellfire. [Ref. 5] Furthermore, the program is leveraging Science and Technology (S&T) investment of over $120 million dollars in 2002, which will further mature enabling technologies for the missile. [Ref. 3] This investment will provide a higher Technological Readiness Level (TRL) for key system subcomponents and allow for a quicker integration of the system to meet an accelerated MS B decision timeline. The program strategy is being developed and is intending to pursue an evolutionary capabilities approach. The approach is a three block incremental plan, which includes the following [Ref. 4]:

Block I – Initial Core Capabilities, which are defined as the following Key Performance Parameters (KPP): Fire-and-Forget, Man-In-the-Loop, Lethality, System Compatibility, and Range.

Block II – Threshold Requirements not addressed in Block I. Primarily extension to base range.

Block III – Service Unique Requirements, which is primarily Navy centric at this time and will include fixed wing platforms employing the missile.

The current program baseline schedule depicts the criticality of this technology being matured and integrated by 2003 to meet a First Unit Equipped (FUE) date within the 2010 fiscal year.

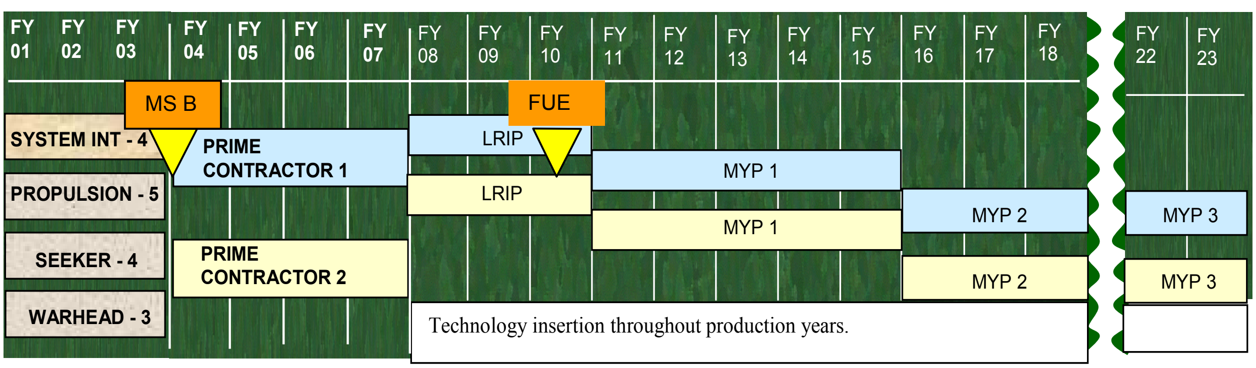



Figure 1. CM Program Schedule [From Ref. 3].

## A. PURPOSE

This research will employ the Janus Combat Model in a Simulation Based Acquisition (SBA) approach to an Analysis of Alternatives (AOA). Janus will be utilized to analyze the military worth of a newly proposed missile named the Common Missile (CM) as compared to its primary alternative the Hellfire Missile (HF). The objective of this research is to investigate which missile is the best operational

alternative for Army Aviation. Additionally, the analysis will provide lessons learned concerning the tactical employment of the missile and in the use of the combat model to support acquisitions. For this research operational effectiveness will be evaluated through standard reports produced by Janus and statistically by analyzing the systems' contributions to platform key measures of effectiveness such as lethality, survivability, and engagement. This analysis will utilize an Army Aviation Deep Attack scenario developed within the Janus Combat Model. This research is a parallel effort not formally tied to the TRADOC Analysis Center (TRAC) managed CM AOA.

## B. RESEARCH QUESTIONS

### 1. Primary Research Question

Using the Janus Combat Model, which missile is the best operational alternative for Army Aviation and to what extent is it better?

### 2. Subsidiary Research Questions

- Utilizing tactics modified to take advantage of CM's new technological attributes, which missile is more effective and to what extent?
- What tactical benefits does the CM and attack aviation combination bring to the battlefield?
- How can Janus results be useful and meaningful to a Program Manager (PM)?

## C. SCOPE AND LIMITATIONS

The scope will include a study of the capabilities of both the CM and the HF missile; a study of the capabilities and limitations of the Janus Combat Model; research on the capabilities of the Longbow Apache Helicopter and tactics employed in the Deep Attack. The preceding research will

support the development of a force-on-force scenario within Janus, which will facilitate the comparative analysis of the two alternative missiles. This thesis will be limited to the application of a single scenario within the Janus Combat Model. It will evaluate only the stated measures of effectiveness (MOEs) developed specifically for this research and will not include ongoing research results produced by the CM Project Office. This thesis will be unclassified and therefore limited in scope by the availability of non-classified data concerning missile-engineering specifications.

## D. RESEARCH LITERATURE AND METHODOLOGY

The methodology used in this thesis research consisted of the following steps:

### 1. Literature Search

- Conducted a comprehensive literature search of project office documents, and DoD regulations.
- Conducted a study of the Janus model reference manuals, past Janus based research projects, articles and other library information resources concerning its use.
- Conducted a study of existing Attack Aviation doctrine and potential future doctrine.

### 2. Data Collection

- Collected unclassified CM seeker engineering specifications and developed a missile model within Janus.
- Further refined the model under the guidance of a PEO-Tactical Missiles operations research analyst.
- Evaluated the draft operational requirements document and operational mode summary for the CM and developed an aviation centric force-on-force scenario within Janus.

- Collected Janus post processor reports from simulation runs of the test scenario using HF as the base case, and CM as the primary alternative case both employing the same tactics.
- Collected data on a third case employing fire-and-forget tactics designed to leverage this technological attribute of the modeled CM.

### 3. Method of Analysis

- Used descriptive statistics to analyze test scenario post processor report output for each of the three cases.
- Compared the HF's operational effectiveness as determined by the statistical analysis to the effectiveness of the CM.
- Compared the results from fire-and-forget case against the results from the base and alternate case comparative analysis to determine the significance of this capability.
- Analyzed these results further from the warfighter's perspective using engagement area calculus and comparing noted pros and cons of employing each missile.

### 4. Synthesis

- Interpreted the data in a manner that facilitates ease of understanding for the non-operations research trained individual.
- Used the results of the statistical and operational comparative analysis to determine which missile is the best operational alternative.

## E. ORGANIZATION OF THESIS

This thesis is divided into six chapters. Chapter I, Introduction, provides a detailed look at the impetus for this research, and the methods employed to conduct the research.

Chapter II, Background, is intended to frame the research in context and provide insight into key

externalities and systems that will influence the study. This includes an overview of the Janus Combat Model, which was the simulation used to execute this study. It furthermore discusses the development process of the missile modeled within Janus.

Chapter III, Scenario Description, provides a description of the tactical scenario simulated within the study.

Chapter IV, Data Analysis Methodology, outlines the statistical and operational analysis by describing how Janus was used to assess the alternatives in a simulated operational environment. It defines the MOEs utilized as the key parameters for differentiation of the missiles within this analytical study. It also describes the basic operational analysis applied within the study.

Chapter V, Analysis of Data, analyzes the raw data in a spreadsheet format and provides the statistical analysis of the MOEs. This includes a graphic statistical portrayal of each missile's performance as compared to the other by MOE. An operational analysis considers the key operational differences between the missiles.

Chapter VI, Conclusions and Recommendations, provides the author's conclusions regarding the thesis research questions. It also includes answers to the subsidiary research questions, which provide insight into employing the Janus Combat Model in a SBA approach and suggested areas for further research on the topic.

### F. BENEFIT OF THIS STUDY

This study will build on the body of knowledge necessary for the Army to extrapolate the best alternative

for the identified mission need, but will not be subjected to the validation requirements enforced upon the project office. It will also provide valuable lessons learned concerning the application of Janus in support of critical acquisition decisions. Furthermore, it will increase the author’s awareness of potential applications of Janus and provide greater understanding of the advantages and disadvantages of the use of models and simulation in support of acquisitions.

THIS PAGE INTENTIONALLY LEFT BLANK

# II. BACKGROUND

This study has many different external factors affecting it, as well as several systems that are integrated to achieve the desired research end state. For the purposes of this thesis, a background of the externalities and systems involved is required to understand the purpose, methodologies employed and findings of this research.

## A. ANALYSIS OF ALTERNATIVES

This study parallels the efforts of the Program Office and the Army's Training and Doctrine Command (TRADOC) to determine the best alternative for the identified mission need. Analyzing alternatives is part of the Cost as an Independent Variable (CAIV) process. An AoA broadly examines multiple aspects of a program's alternatives with a focus on determining the best alternative based on the understanding of technical risk, maturity, cost and price. The analysis must be designed to aid decision makers in judging whether the recommended solutions or replacements for an existing system warrant the cost. In most cases, and as applied in this research, the analysis will consider and baseline against the system that the acquisition program will replace. The Army or Office of the Secretary of Defense (OSD) Program Analysis and Evaluation (PA&E) is charged with ensuring the AoA is comprehensive, and objective. PA&E provides this assessment to the component head, and the Milestone Decision Authority (MDA). The Program Manager (PM) and MDA will consider the analysis, and the assessment provided by PA&E for the Milestone B decision for all Acquisition Category (ACAT) 1 and 1A

programs. An AoA is intended to be quantitative. Its content and conclusions are meant to induce decision makers and others involved in the acquisition to enter into discussion concerning the assumptions and outcomes of the study. This dialog is necessary to establish better program understanding and to ensure everyone involved with the decision-making process plays a role in this critical initial decision. There must be a common thread established through the AoA, defined system requirements, and test and evaluation measures of effectiveness. The AoA will provide insights into the facts surrounding the program and answers to some of the assumptions. It will also direct attention to previously unknown facts or new assumptions identified through the study. In the end, the analysis must outline the relative advantages and disadvantages of the alternatives considered within the AoA. [Ref. 1]

This study is part of an analysis of alternatives to support a requirement for a missile replacement for the Hellfire and TOW missile, which are currently in the Army and Marine Corps inventory. The Common Missile is the proposed replacement and is currently being managed by a Program Office within the Program Executive Office (PEO) – Tactical Missiles. The AoA calls for a three-phased approach (Figure 2). This study focuses on the operational analysis contained within the second phase. [Ref. 2]

| AoA Phase | Phase I | Phase II | Phase III |
|---|---|---|---|
| **Main Products** | • Fire-and-forget Block I Key Performance Parameter (KPP)<br>• CM Logistics impact determination<br>• CM Block II KPP | • Operational Analysis<br>• Cost Analysis<br>• Logistics and training impact analyses | • An update of the AoA including Service unique requirements, if funded. |

Figure 2. CM AoA by Phase [From Ref. 3].

This analysis is intended to focus on the CM as a potential missile solution for Army Aviation. It will specifically address the operational effectiveness of the CM, when employed on the Longbow Apache (AH-64D) attack helicopter. This analysis will employ the author's personal experience as an attack helicopter pilot in a qualitative assessment coupled with a quantitative assessment of the missile using descriptive statistics.

## B. SIMULATION BASED ACQUISITIONS

This study is an example of the use of simulations to support acquisition processes. The Department of Defense (DoD) has established acquisition directives that focus upon the integration of technologies throughout the acquisition process to reduce cost, improve system performance, and reduce the time to field a system. These directives are being carried out through a set of varied modeling and simulation (M&S) tools, which when used together for the above listed purposes are termed Simulation Based Acquisitions (SBA). [Ref. 6] To implement SBA the DoD 5000.2-R further charges the program manager with many tasks related to planning for M&S usage. Key to this thesis are the following requirements [Ref. 1]:

- PMs shall plan for M&S and make necessary investments early in the acquisition life cycle.
- The PM shall use verified, validated, and accredited models and simulations, and ensure credible applicability for each proposed use.
- The PM shall use M&S to assess a system against design to threats and analyze to threats in those scenarios and areas of the mission space or performance envelope where testing cannot be performed, is not cost effective, or additional data is required. [Ref. 1: p. 5-5]

These directives are integral parts to a successful program, but all of them require more than business knowledge to properly carry out. Specifically, the requirement to "ensure credible applicability for each proposed use" suggests that the PM and his staff will place due consideration into what a particular simulation or model can accurately portray and furthermore that they believe the results are actually meaningful to the process.

In the operational world, being technically and tactically proficient is a primary tenet of the profession. This tenet can be applied within the acquisition world as well, when discussing the technical tools of the trade. Obviously some level of technical knowledge must be obtained to employ M&S as a program tool, but less evident is the tactical nature of this tenet's application. The tactical decisions for the program manager are on the business battlefield, which often require important decisions to be made based on M&S results. Understanding what is behind the data that supports these decisions, coupled with the directives established in regulation is part of the impetus behind this study.

The Janus Combat Model enjoys wide usage and acceptance with the acquisition community, as well as in the military operations research community. Janus is currently used by many DoD research agencies and program offices and is available for use at many military installations worldwide. The fact that it is widely used is not only based on its high level of accessibility, but also on its ability to accurately replicate the physics of the systems it is intended to model. These facts make it a worthwhile SBA tool to use within this study, which will be applicable to planning and development in future programs.

## C. OVERVIEW OF THE JANUS COMBAT MODEL

Janus version 7.06DC is utilized for this research. Janus is an interactive, six-sided, closed, stochastic, ground combat simulation featuring high-resolution color graphical user interface. The term "interactive" refers to the man-in-the-loop real time interaction between the person making the tactical decisions and the simulated units and equipment they control. The system is "six-sided" because six or less friendly/enemy forces can be represented in one combat scenario. In the case of this analysis, only two sides will be represented. The term "closed" describes the nature of information flow between the opposing forces. Neither side has perfect knowledge of the activities carried out by the other. "Stochastic" is the manner in which the model functions when analyzing and determining, according to the laws of probability, the outcomes of aspects of battlefield interaction that cannot be predetermined. "Ground combat" captures the focus of Janus, which is on the tactical deployment of ground combat systems and how each interacts. It generates an

environment where the impacts of combat support and service support systems, selected terrain, weather, battlefield obscuration, day and night, and a chemical environment directly affect the combatant units within the simulation. [Ref. 10]

Janus also incorporates the third dimension of the battlefield in its simulation of warfighting. Both rotary-wing and fixed-wing aircraft are represented within the database. Players provide movement direction to the helicopters in real time, using either Nap of the Earth (NOE) or a high altitude/high airspeed profile. The simulation algorithm for a helicopter then prescribes the movement at the stationary Firing Position (FP) or within the bounds of an Attack by Fire Position (ABF). The helicopters will pop up from a low hover to a high hover, scan the terrain within their Line-of-Sight (LOS) and then drop back down to a concealed low hover. In the concealed or masked position the player can analyze the results of the scan and determine which targets to engage. This maneuver is repeated until they detect and engage a target or are ordered to move. Helicopters within Janus can deliver missiles, terminally guided munitions (TGM), rockets, and large caliber gunfire, e.g. 30 mm.

The scenario planner in preparation for the simulation establishes weather conditions. These parameters are based on a defined season of the year, visibility, and terrain type. Weather data sets within Janus incorporate wind speed and direction, cloud ceiling, relative humidity, temperature, inversion factor, sky-to-ground brightness ratio, and ambient light level. These are all of keen

concern to this analysis due to the impact of these conditions on target acquisition by the firing platform.

Target acquisition capability within the simulation is assessed by two factors. First, the firing platform must have an uninterrupted LOS to the target. Intervisibility with the target is the most critical factor. Second, the firing platform's sensor, as influenced by the weather, battlefield conditions, and range to target, must be such that the sensor can still detect the target. These determinations are accomplished through established algorithms, which may not be modified by the player or analyst. Third, optical and thermal sensor characteristics and performance parameters are critical to the acquisition and are of particular interest within this analysis. The firing platform, AH-64D, and the CM have some form of sensor, which must be replicated to accurately model the missile's performance. Janus allows the analyst to define the field-of-view size of the sensor, spectral band, and mean resolvable temperature and mean resolvable contrast (thermal and optical) as a function of cyclical rate. The core Janus data for acquisition sensors was developed and provided by the Night Vision and Electronic Sensors Directorate (NVESD). The data were further augmented for this analysis with thermal and optical input gained from the CM Project Office regarding seeker-engineering specifications for the concept CM. [Ref. 17] These specifications apply solely to the missile seeker and not to the helicopter targeting optics.

The terrain in Janus is based on digitized terrain elevation data developed by the National Imagery and

Mapping Agency (NIMA). Maps of 1:50,000 scale are integrated into the terrain database and provide features such as contour lines, roads, rivers, and vegetation. A "Polygonal" terrain feature representation is the basis for the graphical user interface. For this analysis a terrain file of southern Poland will be utilized. This file is maintained by TRADOC Analysis Center - Monterey (TRAC-MTRY) and is also utilized for analysis by TRADOC Analysis Center – White Sands Missile Range (TRAC-WSMR). Furthermore, TRAC-Leavenworth (TRAC-FLVN) and the project office have used the same terrain to support their AoA. [Ref. 17]

## D. MODEL INPUTS

This analysis required the input of conceptual engineering data provided by the program office into the Janus database to develop a working model of the CM. The existing database provided by TRAC-MTRY contains models of the AH-64D and assorted threat systems that will also be used in this analysis. The input data setup is the most critical and complex aspect of using Janus. It is further complicated because inherent, subtle relationships between different types of data may not be intuitively obvious and can lead to some inevitable surprises. [Ref. 10: pp. 2-11] These include inputs for system performance data such as weapons accuracy based on probability of hit, and lethality based on probability of kill given a hit. Operational input regarding the system includes specific aspects of the firing/engagement cycle such as acquisition time, reload time, time between trigger pulls. The system's doctrinal or envisioned tactical plan dictates other critical operational data to input. These inputs include target type rankings for engagement planning or round selection

priorities. The critical model inputs for the systems utilized for this study, their weapons, and sensors are described in the following sections.

### 1. System Model Inputs

The system is defined for this study within the Janus database as the AH64DCM and is based on the existing AH-64D model within the Combat Systems Database (CS data). The system section of the database retains the AH64DCM as an amalgam of the aircraft, its associated target acquisition system and on board weapons.

The system characteristics section retains the AH64DCM's basic operational data. This section includes the specifications for maximum aircraft speed, maximum visibility, and weapon range. All of the basic aircraft parameters were copied from the existing AH-64D model within the CS data with the exceptions of maximum visibility, which was increased from 9 kilometers to 20 kilometers. This unclassified figure represents the expected capabilities of future onboard targeting sensors and was developed based upon input from modeling personnel from the Project Manager's Office (PMO). [Ref. 17] The maximum effective weapon range was extended from 8 to 12 kilometers to represent the unclassified threshold for air-to-ground attack by the CM. A basic load of 16 missiles was modeled for the AH64DCM, which equals the basic load of the HF equipped AH-64D.

### 2. Weapons Model Inputs

The CM model was based upon a copy of the HF missile model already within the CS data. The HF based data were confirmed against the data residing in the project office's database prior to modification. The aim and reload times,

rounds per trigger pull, and round velocity were not changed in the CM model once copied from the HF model. The weapon model developed from this process was named Common Missile Direct Fire or CM DF, as denoted in the database. Additional inputs required for the development of the model are the round guidance, probability of hit ($P_H$) and probability of kill ($P_K$) tables.

The round guidance establishes the model parameters for how the missile is guided to the target. This includes information on the guidance mode utilized by the aircraft in tandem with the missile seeker, the capability to fire on the move, and the sensor type. The model guidance was changed to reflect the CM fire-and-forget capability. In the base case, HF versus CM, a restricted CM model not capable of fire-and-forget was used to evaluate the benefits gained by the basic improvements in missile technology between the two variants. In the final case, fire-and-forget was applied in an unrestricted guidance mode. This essentially means the aircraft can fire and move at will. Terminal guidance of the missile was not required in this mode.

Probability of hit is defined as the probability of hitting a target at a given range with a single trigger pull. Probability of kill is defined as the probability of killing a target given a target hit. Both $P_H$ and $P_K$ are functions of range. Janus uses a probability function to describe the $P_H$ and $P_K$ for a given weapon as a function of range. Moreover, a random seed was utilized during each run of the scenario, which further influenced this probability function. This in turn created independent

outcomes from each run. Unclassified $P_H$ and $P_K$ information for Common Missile was provided by the modeling personnel from the PMO. [Ref. 17]

### 3. Sensors Model Inputs

The sensor is defined in Janus for both the firing platform and the missile seeker. Since the HF and CM are both fired from the AH-67D, no changes were made to the aircraft onboard sensor other then range. The aircraft Forwarding Looking Infrared (FLIR) sensor, its field-of-view, and spectral band to include supporting mean resolvable temperature tables (cycles per milliradian versus temperature or contrast) remain the same for both cases.

The concept CM is a tri-mode seeker. This type of seeker cannot be accurately replicated in Janus, but has been represented in the sensor section of the database as a millimeter wave and infrared capable missile. The HF is modeled as a laser guided missile only. The Longbow HF millimeter wave guided missile is not utilized. This is because the fielding plan calls for the replacement of the HF II missile by the CM prior to 2010, which is the timeframe, used for this AoA. [Ref. 2]

## E. MODEL OUTPUTS

Key to this study is the capability of Janus to support battle analysis. Battle results can be viewed on the Janus Analyst Workstation (JAAWS) and the Janus Plan View Display (JANPVD). Both of these options provide the capability to replay the battle exactly as it ran during the simulation. For quantitative analysis this graphic output is insufficient, but JAAWS and JANPVD also support selective retrieval of critical system and force data

resulting from the simulation. This data once selected can be printed as a detailed battle report, which is usable for analysis.

The development of a scenario within Janus will be required to support this analysis. Scenario development is the process of selecting specific systems and weapons, terrain, force structures, and battlefield conditions to be represented in the scenario. This requires detailed planning down to the tactically correct placement of those systems and weapons on the simulated terrain. It also includes the development of command and control overlays within the database. To effectively run a scenario all of the above processes must be completed. The standard development sequence of events, which was used for developing this study scenario, is outlined in the figure 3 below. [Ref. 10: pp. 2-14]

After the scenario has been developed and verified, it is ready for execution and analysis. The completed scenario can be maintained, and interacted with on demand. The results of each simulation are stored in a sequential file for later analysis.

**SCENARIO DEVELOPMENT PROCESS**

- Use the Terrain Editor (TED) to create or modify the terrain file to be used by the scenario.
- Use the Symbol Editor (SYMBOLS) to create or modify the two symbol files to be used by the scenario.
- Use the Combat Systems Data Editor (CSDATA) to review and/or modify performance characteristics of systems to be used in the scenario.
- Use the Scenario Forces Editor (FORCE) to create or modify military forces (Force File) to be used by the scenario.
- Use the Command and Control Overlay Editor (COED) to perform tactical planning by drawing command and control graphics before or during scenario execution.
- Scenario initialization and merging can be used to modify existing scenarios or create new scenarios.
- Use the Janus scenario verification programs (VFYSCEN and GRAFVFY) to verify the accuracy and completeness of the weapons and systems data to be used by the scenario.
- Execute the Janus scenario
- Analyze/review the results of the scenario execution (programs POSTP, and/or JAAWS and JANPVD).

Figure 3. Janus Scenario Development [From Ref. 10].

## F. DESCRIPTION OF THE COMMON MISSILE

The CM will be an advanced non-kinetic energy missile optimized to defeat individual point targets listed in the Systems Threat Assessment Report (STAR) at maximum standoff range, while minimizing the exposure of the firing platform to enemy fire. The same missile will be employed by both

ground and air platforms. The intended target spectrum includes bunkers, transporter-erector launchers (TELs), radar sites, tracked armor, command sites, and patrol boats. [Ref. 7: p. 3] The missile will have a multi-mode seeker incorporating semi-active laser (SAL), infrared (IR), and millimeter wave (MMW) technologies to allow for line-of-sight, non-line-of-sight, and beyond line-of-sight engagements. It will incorporate generation IV counter active protection system technology, making it effective against all current and projected threats through 2015. The multi-mode seeker enables all weather employment and increases probability of hit in both a man-in-the-loop and fire-and-forget modes of operation. The CM model studied will have a maximum range of 12 km and an improved lethality over the legacy systems it is intended to replace. Moreover, the missile will utilize a gel-based propellant that will reduce launch signature, while still increasing the standoff. Due to advances in warheads the CM lethality will increase, while the overall weight of the missile will decrease. The missile is to not exceed the weight of the current TOW missile, which is 70 pounds. [Ref. 8]

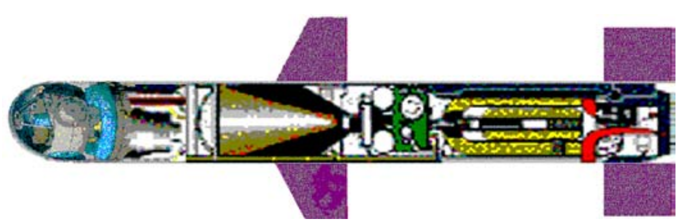


Figure 4. Concept Common Missile.

### G. DESCRIPTION OF THE HELLFIRE MISSILE

The Hellfire (HF) provides heavy anti-armor capability for attack helicopters. HF employs a SAL seeker to home in on a laser spot that can be projected from ground observers, other aircraft, or the launching aircraft itself. This enables the system to be employed in a variety of modes: autonomous, remote, single shot, rapid, or ripple fire. In an indirect engagement its target designation is accomplished by one aircraft, while another servicing aircraft provides the remote fire. The HF missile features dual warheads for defeating reactive armor, electro-optical countermeasures hardening, semi-active laser seeker, and a programmable autopilot for trajectory shaping. The AGM-114K missile known as the Hellfire II is the version that will be utilized as the baseline for this analysis. This missile has an unclassified maximum effective range of 8 km and weighs 100 pounds. It is capable of operating with either pulsed radar frequency or A-Code laser codes for those aircraft equipped with dual code capability. Hellfire II incorporates many capabilities including the ability to overcome laser obscurant/backscatter generated by dust, smoke, or weather, which negatively affects most laser guided missiles on the battlefield. Other features include electro-optical countermeasure hardening, target reacquisition capability, an advanced technology warhead system capable of defeating reactive armor configurations projected into the 21st century, reprogramability to adapt to changing threats and mission requirements, and shipboard compatibility. [Ref. 9]

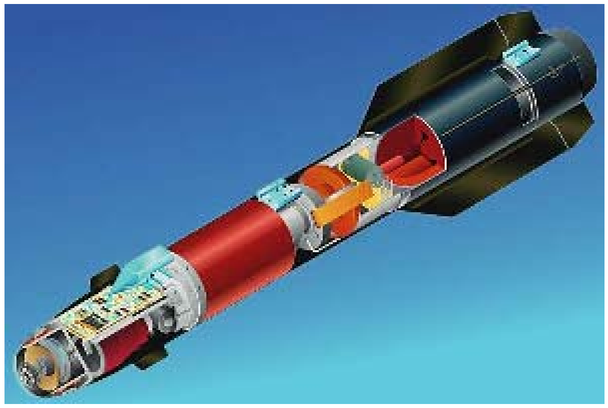


Figure 5. Hellfire II.

## H. DESCRIPTION OF THE LONGBOW APACHE (AH-64D)

The AH-64D will be the firing platform for this study of the CM. The AH-64D Longbow Apache is a modernized A model Apache equipped with a mast mounted fire control radar (FCR), a radar frequency interferometer (RFI). The AH-64D has a maximum payload of 16 fire-and-forget radio frequency (RF) guided or semi-active laser (SAL) guided Hellfire missiles, 1,200 rounds of 30mm High Explosive Dual Purpose (HEDP) munitions, and 72 Folding Fin Aerial Rockets (FFAR) of various types. The aircraft has a maximum gross weight limitation of 21,000 pounds, and the number of available wing hard points is the only restriction to its weapons load. A typical mission load is 16 HF missiles, and 600 rounds of 30mm. [Ref. 13] The aircraft’s maximum fuel capacity is 260 gallons of fuel, which gives it an average mission duration, at sea level and low ambient temperature, of two and one half hours. It also includes a digital communication suite, and automatic target classification system. Dual standard 1553 buses support all of these electronics. [Ref. 22]

The FCR can detect, classify, and prioritize up to 128 targets and define them as tracked, wheeled, air defense, unknown, helicopter or fixed wing aircraft. The RFI is a passive electronic support measure system that provides for the detection, acquisition, identification, classification, location and prioritization of radar emitters. It is designed to detect and acquire threat emitters well beyond their lethal range before they can detect the Longbow Apache. The RFI is primarily an offensive system providing narrow field-of-view (FOV) target cueing for onboard and off board sights/sensors for the accurate and timely employment of weapons. Onboard sights include second generation Forward Looking Infrared (FLIR) for targeting and navigation, low light television, and optical.

The combination of the FCR, the RFI, and the advanced navigation and avionics suite of the aircraft provide increased situational awareness, lethality and survivability for the AH-64D. Dual embedded GPS/Inertial Navigation Systems (EGI) permit the Longbow Apache to conduct precision maneuver, engagement and attack. Targets acquired by AH-64D sensors with data detailing threat classification and location, along with speed and direction of movement, can be digitally transmitted to other Longbow Apaches as a target handoff or for remote shots. This data may also be passed to the Army Airborne Command and Control System (A2C2S), to the Joint Surveillance Target Attack Radar System (J-STARS) or to the aviation and ground commander's Tactical Operations Center (TOC) through the Common Ground Station (CGS). From the CGS this data can be provided to other elements of the combined arms team through the All Source Analysis System (ASAS). Information

derived from Apache sensors can fill voids in the relevant common picture and expand the battle space when sensor-to-shooter linkages are met. [Ref. 11: p. 1]

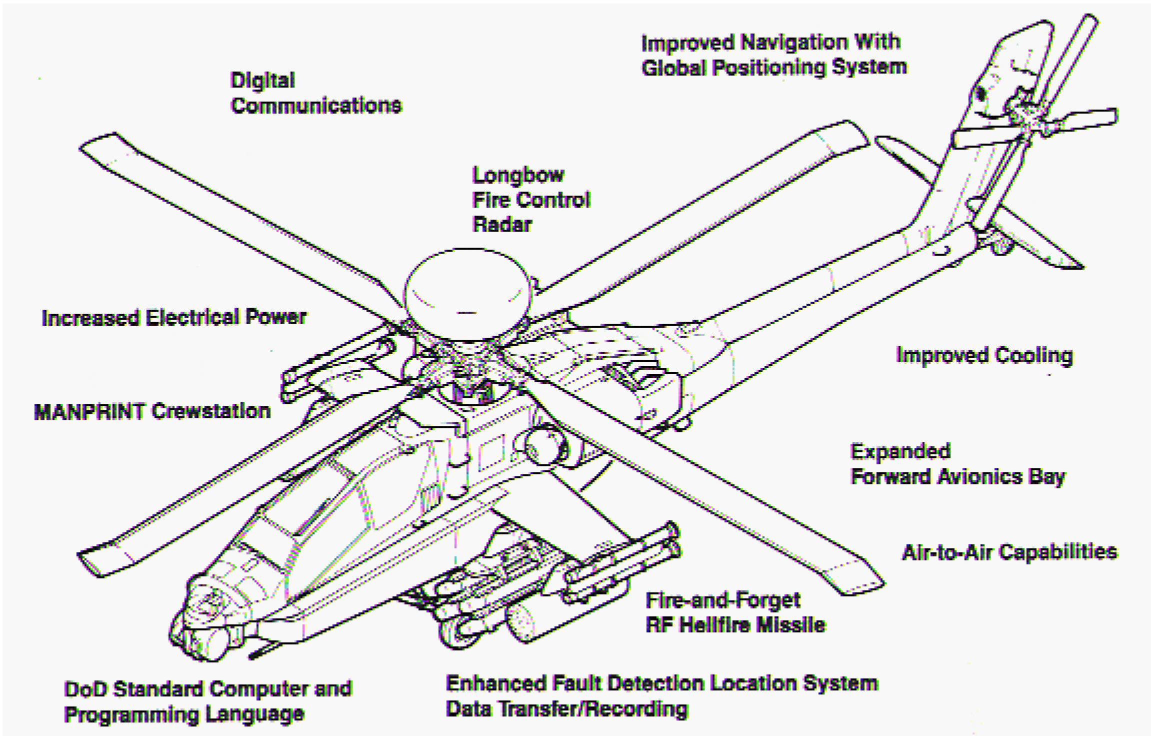



Figure 6. Longbow Apache Helicopter [From Ref. 22].

In summary, this overview of the many different external factors and systems involved with this study lays the groundwork for understanding the purpose and findings of this research. The next chapter of the study will assimilate these factors and systems into a scenario tailored for the required analysis.

# III. SCENARIO DESCRIPTION

To support this analysis an attack helicopter company (ATKHC) equipped with the AH-64D represented by eight modeled entities is employed in a force-on-force scenario. This scenario is based on an ATKHC in a deep attack to support a heavy division's operations. The same tactical scenario is utilized for each case analyzed. The opposing forces (OPFOR) consist of a multiple rocket launcher (MRL) battalion supported by a tank company. The OPFOR also includes a platoon of air defense artillery (ADA). The OPFOR is represented by 32-modeled entities.

The paragraph below doctrinally defines the deep attack [Ref. 12: pp. 3-20]:

> Deep operations may be conducted simultaneously with close and/or rear operations. Deep operations comprise activities directed against enemy forces not in contact with friendly ground forces. The objective of deep operations is to delay, disrupt, or destroy enemy forces, facilities, and high-payoff systems. These activities are designed to influence the conditions in which current/future close operations are occurring or will occur. At the tactical level, deep operations shape the battlefield to obtain advantages in subsequent engagements. Successful deep operations create the conditions for future victory. The principal targets of deep operations are the freedom of action of the opposing commander and the coherence and tempo of his operations.

To support a deep attack the ATKHC moves across the Forward Line of Troops (FLOT), which is established along a major east-west river, to attack the OPFOR. This attack scenario employs only the ATKHC's organic weapons against

the OPFOR unit, which is established in a stationary firing position. See Figure 7 for the basic ATKHC scheme of maneuver. The remainder of the OPFOR division is not represented in the scenario. After traveling approximately 135 km at a 100 knot ground speed to the designated Attack –by-Fire Positions (ABF) for this attack, the ATKHC has 30 minutes to engage the target and return to base (RTB) due to fuel limitations. The commander’s intent for this attack is to destroy the MRL battalion and its supporting elements. The doctrinal criteria for destruction equates to 70 percent (22 vehicles within this scenario) of the OPFOR being destroyed. [Ref. 14] For purposes of this analysis the time allotted for each simulated run is 40 minutes. Ten minutes of this time is allocated to movement from the company release point along attack routes to each of the platoon’s ABF positions.

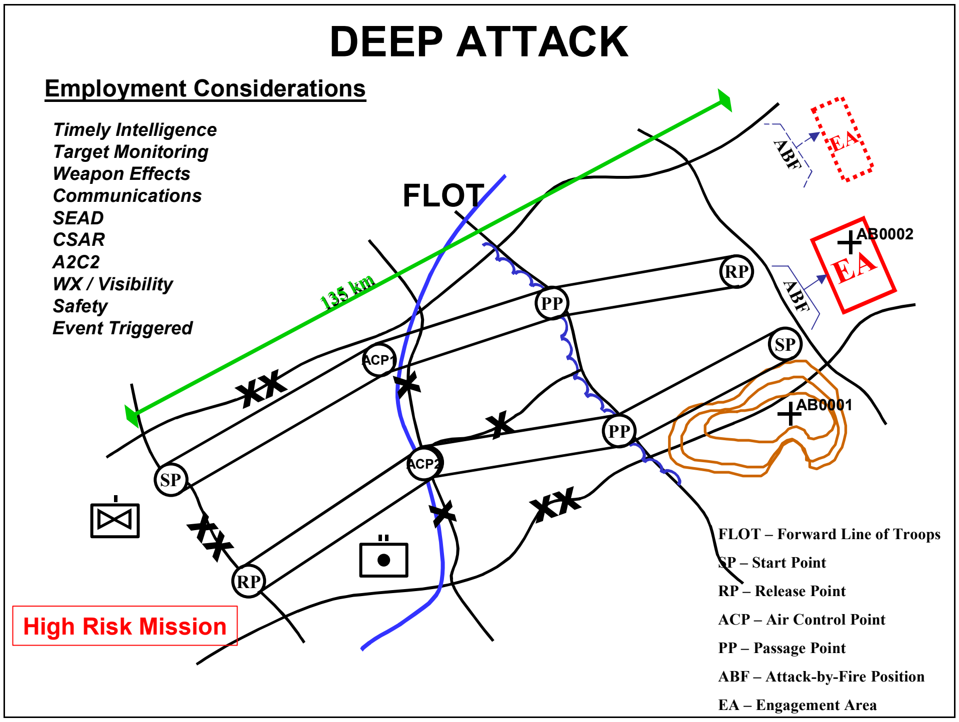



Figure 7. ATKHC Deep Attack.

## A. TERRAIN

The scenario utilizes a 15-meter resolution terrain file of southern Poland. The CM Program Office selected Poland as the terrain for their Janus CM study. [Ref. 17] This terrain file is used within this study to apply a similar tactical rigor to this research's deep attack scenario. This terrain is best defined as rolling terrain, heavily forested, with significant restricted terrain due to streams and rivers. The road networks within the terrain are primarily dirt/unimproved roads with access to paved roads available heading in all cardinal directions. The vegetation and rolling hills provide challenging terrain to achieve shooter to target intervisibility from great distances.

## B. ATTACK COMPANY STRUCTURE

The ATKHC of Longbow Apaches consists eight aircraft divided into two platoons of four aircraft. The company mix consists of three aircraft equipped with FCR and five without the radar. The ATKHC fights in teams. In this study four teams of two will be employed. Three teams will consist of one FCR aircraft and one without radar. One team will be without radar capability. ATKHCs often are employed independent from the battalion, but would be employed with other ATKHC should the commander determine a continuous attack is required to ensure that his intent is met. In this case, one company is deemed sufficient to destroy the multiple rocket launcher battalion.

## C. ATTACK COMPANY TACTICS

A deep attack operation has three major phases. The enroute phase, the actions on the objective phase, and return to base. [Ref. 14] Only actions on the objective will be simulated for this study. Enroute operations and the return to base, while critical facets of a deep attack, do not set the conditions for evaluating the effectiveness of the CM. Actions on the objective include the actual attack on the primary target set within the company's preplanned engagement area (EA), and any additional movement required to acquire and attack OPFOR to meet the commander's intent of 70 percent of the OPFOR battalion's systems destroyed. The company will move in teams of two and occupy the ABF as a platoon. The team will be in a lead-wingman formation with the FCR equipped AH-64D in the lead. The FCR aircraft will scan the battlefield as the team moves into the BP and once established will scan the designated EA for targets. The team will engage any

targets encountered during movement to the ABF. Targets acquired by the RFI would be passed digitally via a radar frequency handover (RFHO) to the wingman for a team solution and attack, but this capability is not replicated in Janus. Immediate threats to the aircraft will be attacked autonomously. The figure below depicts the lead-wingman concept that will be utilized in this scenario. [Ref. 13: p. 2]

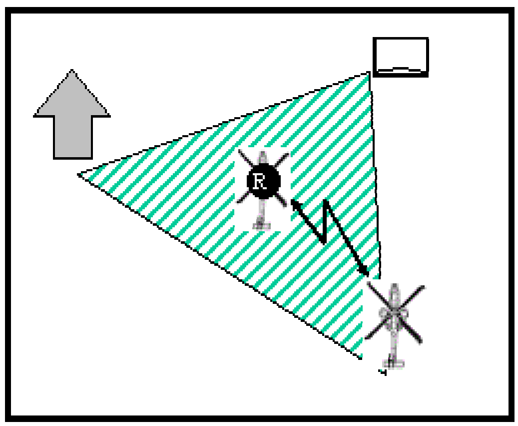


Figure 8. Lead-Wingman Formation detecting ADA.

Once established in the ABF the company will engage targets in the EA and subsequent targets of opportunity utilizing a company fire distribution plan. This plan assigns scan sectors for engagement for each of the teams in the company. The intent of the fire distribution plan is to prevent multiple missiles being fired at the same target and, in the end, ensures the efficient destruction of the OPFOR unit. The fire distribution plan is a tactical tool and is dynamic. Due to unforeseen circumstances such as a target of opportunity or the OPFOR not being positioned within the EA, the commander will establish a new fire distribution plan during the attack.

An example of a fire distribution plan is portrayed below. [Ref. 13]

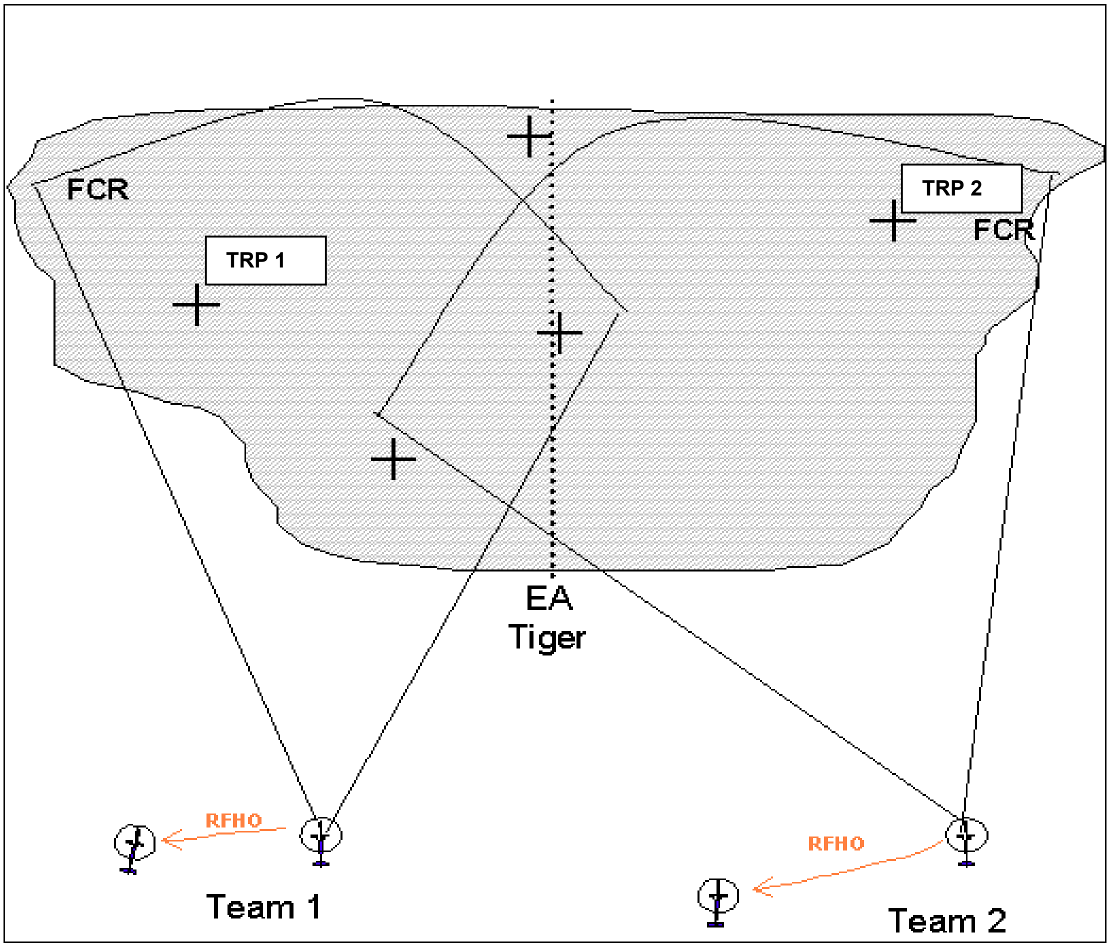



Figure 9. Fire Distribution Plan.

## D. OPFOR UNIT STRUCTURE

The MRL battalion is comprised of 18 122-mm, BM-21 systems. These rocket artillery systems are truck mounted. The battalion is broken down into three firing batteries of six BM-21 systems each, a headquarters and control platoon, and a service and supply platoon. For this simulation only the firing batteries will be replicated. Additionally, the

MRL battalion is task organized with a tank company to increase their survivability, during the offensive. The tank company is comprised of ten T-72 tanks, which are broken down into three tank platoons. Each platoon consists of three tanks. The commander's tank is the remaining tank and is placed to supervise and weight the company's main effort. The MRL battalion is further supported by a platoon of 23-mm Anti-Aircraft (AA) Guns, ZSU-23-4. This platoon consists of two sections of two guns, which have been task organized with two of the tank platoons. [Ref. 16]

## E. OPFOR EQUIPMENT DESCRIPTIONS

The OPFOR systems utilized for this analysis were taken from the existing Janus Combat Systems Database and are the same OPFOR systems utilized by TRAC in their analysis efforts regarding the CM. The BM-21, T-72, and ZSU-23-4 are well-proliferated systems, which can be expected to be encountered by the CM equipped AH-64D throughout the 2010-2015 timeframe.

The T-72 model is equipped with a 125mm smooth bore main gun, which has a maximum effective range of 4,000 meters. The main gun is capable of engaging and destroying the AH-64D. It is also armed with a 12.7mm machine gun with a max effective range of 1,200 meters. The model of tank utilized for this scenario is also armed with an AT-11 missile, which is highly effective against helicopters out to 5,000 meters. The tank is equipped with a ballistic computer for firing solutions against ground and air targets and has thermal imaging capabilities. See Figure 10. [Ref. 23]

Figure 10. T-72 Main Battle Tank.

The 122-mm BM-21 systems are not equipped for self-defense against an airborne threat. The firing batteries of BM-21s are laid in firing positions oriented towards the ATKHC avenue of approach and do not move during this scenario. The batteries are positioned tactically with dispersion to act as a passive defense against direct or indirect fire attacks. They rely solely on the firepower provided by the task organized armor/air defense platoons for protection. See Figure 11. [Ref. 24]

Figure 11. BM-21 Multiple Rocket Launch System.

The modeled ZSU-23-4 is a four-barreled 23-mm anti-aircraft weapon integrated into a tracked chassis. The system does use radar for range to target, but engages using its primary optics only. The optics are effective out to 2,500 meters. The round utilized by the ZSU-23-4 is highly effective against the AH-64D. The ZSU-23-4 relies heavily in this scenario on cover and concealment to ensure survivability up to the point of engagement. See Figure 12. [Ref. 25]

Figure 12. ZSU-23-4 Air Defense System.

## F. OPFOR TACTICS

The MRL battalion poses a considerable threat to the friendly division's rear and is considered a high payoff target (HPT) by the division commander. This MRL battalion is assigned to the self-propelled artillery regiment organic to the OPFOR tank division. [Ref. 16: p. 21] The division commander has positioned the rocket artillery to

support offensive operations. The MRL battalion is firing under centralized control in support of the division's main attack axis. However, it could also conduct rapid maneuver to any axis, as required, to inflict losses on main friendly groupings.

For this simulation the battalion is established in a notional assembly area (AA) and have laid its tubes to support an upcoming offensive. The initial scenario conditions positions each of the three firing batteries within an independent 2 km square area to facilitate communications and centralized fire control. They have access to a road network, but will not attempt to retrograde from the AA when they come under direct fire. The OPFOR will employ its task organized tank/ADA teams as an overwatch element, while the MRL battalion is in its firing positions. The overwatch elements are initially positioned on high ground within 1 km of the AA. Their systems are oriented on high-speed avenues of approach to the AA. The overwatching tank/ADA teams will engage any threat within range of their primary weapon systems. [Ref. 15]

In summary, this chapter provides the conditions under which the evaluated systems will operate under and the tactics that will be applied by both friendly and OPFOR modeled entities. Understanding the mechanics of the scenario is key to interpretation of the forthcoming data produced by Janus. The detail applied to the scenario development is a key factor influencing the resultant research conclusions. This chapter shows that detailed consideration was given to the development of a scenario,

which appropriately supports this study. In the next chapter the manner in which the alternative missiles will be evaluated is described.

THIS PAGE INTENTIONALLY LEFT BLANK

# IV. DATA ANALYSIS METHODOLOGY

## A. OVERVIEW

The ATKHC will execute attacks utilizing the same scenario equipped first with the HF, and then with the CM. The HF simulation will act as a base case for comparison. The ATKHC will employ the missiles in a direct fire mode and will utilize the same tactics in both of these cases. Twenty-five iterations of each case will be run. The raw data from these runs is presented in Appendix B. Each run will produce an engagement report and coroner’s report for further analysis. A third case will be run, which will have the ATKHC employing the CM in a fire-and-forget mode designed to identify the significance and operational benefits of the CM new technical attributes. This iteration is compared to the first two cases, and will provide operational insights into the CM’s future employment. Each iteration will run 40 minutes, which represents ten minutes of enroute time from the release point (RP) to the ABF and 30 minutes of on station time for the ATKHC. The analysis will examine three primary MOEs lethality, survivability, and engagement as a basis of comparison between the missile types. The analysis will also consider several additional data requirements, which are intended to support and add depth to the evaluation of these MOEs. The analysis of data generated by the simulation runs are broken into two parts: a statistical analysis, and an operational analysis.

## B. STATISTICAL ANALYSIS

The data will be analyzed by utilizing Excel and a statistical add-in named “Analyse-it”. [Ref. 26] The post processor reports provide the raw data from each run, which will be input into the Excel spreadsheet. The statistical analysis utilizes descriptive statistics to examine the raw data. Mean, standard deviation, and range of the data from each run will be examined and compared by Measure of Effectiveness (MOE). This comparison will be graphically supported by the use of side-by-side boxplots.

The boxplot provides a quick impression of the distribution of data. It depicts the median of the data by a centered straight line, and the area to either side of the median represents the spread of the central 50 percent. The area corresponding to 1.5 times the interquartile is represented by the dotted line. Values that occur beyond 1.5 times the interquartile range are shown as outliers by a plus symbol. Values over 3.0 interquartiles away are depicted as circles. The line with a diamond on it represents the samples parametric statistics. The diamond shows the mean and the requested confidence interval around the mean. The parametric statistic is a standard output from the Anaylse-it software, but will not be used during this analysis. The combination of the descriptive statistics comparison of each MOE and the boxplot constitutes the statistical analysis. The additional data requirements evaluated will be analyzed solely through descriptive statistics.

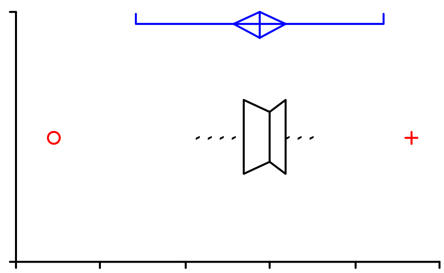


Figure 13. Side-by-Side Boxplot Example.

## C. MEASURES OF EFFECTIVENESS

This study will concentrate on three MOEs to detect any discernible differences between the two missile types. The MOEs are derived from the KPPs, as well as critical operational issues for the employment of the CM by attack helicopters.

### 1. MOE 1 – Lethality

Lethality is designated a KPP for the CM. [Ref. 7] The CM is intended to deliver a greater single shot probability of kill (sspk) than the HF missile. Each force-on-force battle simulation will be evaluated by the following criterion:

- The total number of threat systems killed by each missile type.

### 2. MOE 2 – Survivability

This MOE is measured by the ability of the AH-64D to survive the engagement. This MOE is also a critical operational issue for attack aviation. Consideration of the benefits to survival provided by each missile type will be evaluated by the following criterion:

- The total number of attack helicopters killed by threat weapon systems.

### 3. MOE 3 – Engagement

The ability of the missile and AH-64D combination to engage targets will be determined by the ability to hit and kill the target at the greatest ranges. The ability to engage encompasses the ability to detect. The objective is to identify the missile, which provides the maximum standoff and kill capability. This parameter will be measured by:

- The average range of a shot, which resulted in an OPFOR kill.

### 4. Additional Data Requirements

Additional data requirements that support the evaluated MOEs will be included in this study to provide additional depth and benefit to the analysis. Each missile will also be further analyzed by examining the following criteria:

- The missile's kill efficiency will be evaluated by examining the threat killed/missiles fired. This measure will provide additional insight on lethality.
- The average OPFOR system to aircraft kill range will be evaluated. This measure will provide additional insight on the missile's impact on aircraft survivability.
- The minimum and maximum range, which resulted in an OPFOR kill.

## D. OPERATIONAL ANALYSIS

The operational analysis will be largely qualitative in nature. It will be based upon the experience of the author as a doctrine developer, attack helicopter pilot, instructor, and company commander. This analysis will examine the perceived tactical benefits of the CM as compared to the HF missile within the simulated deep attack

scenario. The resulting analysis will identify what the AH-64D and CM combination bring to the battlefield from the warfighter's perspective. Additional analysis will include a quantitative examination of each missile type based upon Engagement Area Calculus. Engagement Area Calculus is a tool utilized by the tactical planner of attack aviation operations to determine how many aircraft and munitions will be needed to achieve the commander's intent. This determination is largely based upon threat force size and the kill efficiency of the primary weapon system to be employed. In this scenario, the commander's intent is to destroy the MRL battalion and supporting elements, which equates to 70 percent of the OPFOR systems or 22 out of 32 systems destroyed. The results of the application of this procedure against the CM and HF cases will be compared to determine if there is a significant difference in the resources required to accomplish this destruction mission.

THIS PAGE INTENTIONALLY LEFT BLANK

# V. DATA ANALYSIS

## A. OVERVIEW

The primary thrust of this research is to determine which missile is the best operational alternative for Army Aviation and to determine to what extent it is better. This chapter will analyze the raw data produced by Janus and contained in Appendix B. The intent of this analysis is to produce an interpretation of the data, which does not require an extensive background in operations research. Therefore, the central metric used to evaluate the extent to which one missile is better than the other is the mean of the MOEs analyzed. Additionally, standard deviation (SD), median, and the 95 percent confidence interval (CI) for each MOE will be provided.

Data for analysis of each MOE were collected from 25 simulation runs of each case. The cases are identified as HF Baseline (Janus scenario 245), CM Direct Fire (Janus scenario 255), and CM Fire-and-Forget (Janus scenario 235).

Several key factors should be considered prior to examining this analysis. The data were analyzed considering all outliers. Each run required Human-in-the-Loop (HITL) interaction, but was limited to providing a "Go" command for the disaggregated unit movement from ABF 1 to ABF 2. Both the HF Baseline and CM Direct Fire case were executed in an identical fashion. A battlefield graphic is provided in Appendix D. In the CM Fire-and-Forget case the HITL interaction required plotting the point of impact for each Fire-and-Forget missile launched.

The data analysis is broken down into two primary parts: a statistical analysis, and an operational analysis.

## B. STATISTICAL ANALYSIS

### 1. MOE 1 – Lethality

Lethality is defined as the total number of threat systems killed by each missile type.

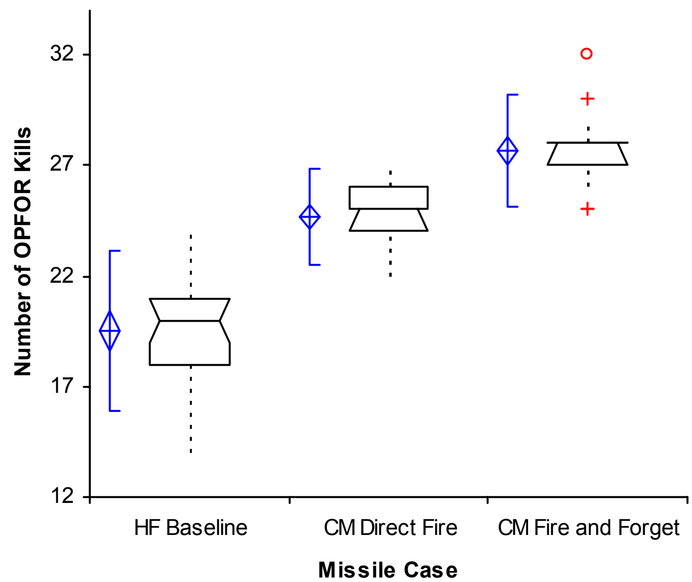



Figure 14. Boxplot MOE 1 – Lethality.

As depicted within this comparative boxplot, the number of OPFOR kills by missile type increases from the HF Baseline to the CM Direct Fire case. These two initial cases reflect the employment of the missile using identical tactics and the missile in a direct fire mode only. Moreover, a marked increase in kills can be seen between the CM Direct Fire case and the CM Fire-and-Forget case. It follows that the CM Direct Fire case displays a

significant increase in kills when compared to the HF Baseline case.

The CM Fire-and-Forget outliers are significant in that they show, in one case, that the potential of 32 kills out of 32 OPFOR entities does exists. This highlights that tactics, which optimize the CM employment, have the potential of further shifting the mean OPFOR kills to this maximized number. This opportunity was not evident in the data produced within the HF Baseline or CM Direct Fire cases.

| | n | Mean | SD | Median | 95% CI of Mean |
|---|---|---|---|---|---|
| **HF Baseline** | 25 | 19.5 | 2.18 | 20.0 | 18.6 to 20.4 |
| **CM Direct Fire** | 25 | 24.6 | 1.32 | 25.0 | 24.1 to 25.2 |
| **CM Fire-and-Forget** | 25 | 27.6 | 1.55 | 28.0 | 27.0 to 28.3 |

Table 1. Descriptive Statistics for MOE 1 – Lethality.

The descriptive statistics highlight the significant increase in mean kills between each missile type throughout each case. The mean lethality increases by 5.1 OPFOR kills, or 26 percent, between the HF Baseline and CM Direct Fire cases. The mean of the CM Fire-and-Forget case represents a 42 percent improvement over the HF Baseline case. The 95 percent CI shows that, with a high level of certainty, CM will outperform HF in both DF and Fire-and-Forget cases.

### 2. MOE 2 – Survivability

Survivability is defined as the total number of attack helicopters killed by threat weapon systems.

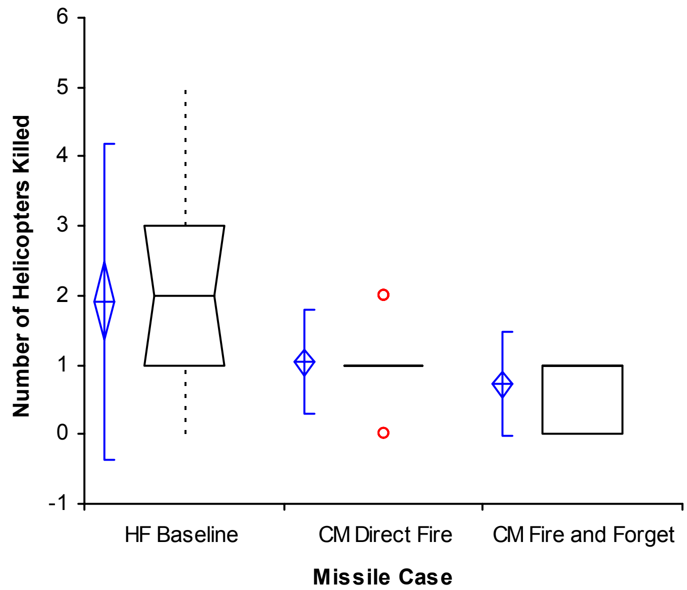



Figure 15. Boxplot MOE 2 – Survivability.

Survivability shows a marked improvement from the HF Baseline case to the CM Fire-and-Forget case. The median number of helicopters killed is higher for the HF Baseline case and can be attributed primarily to the shorter effective range of the missile as compared to the CM. The HF equipped helicopter must close within 8 km of its intended target and therefore tends to expose itself more often within the threat's weapon system effective range. The CM firing helicopter, in both cases, benefits from the increased capability in effective range. This allows the CM equipped aircraft additional time to identify, target, and eliminate high threat OPFOR equipment prior to closing within the OPFOR entities' primary weapon's system range (T-72, AT-11 missile effective range is 5 km). [Ref. 23] The straight line representing the median and interquartiles of the CM Direct Fire case suggests that an

extremely high level of confidence exists that the median number of helicopter kills depicted will occur. The identification of observations of two helicopters killed and zero killed versus one have been labeled far outliers. This observation is deemed to be not significant. The median of the CM Fire-and-Forget case suggests further improvement of survivability over the CM Direct Fire case and clearly suggests that the expected number of CM equipped aircraft killed during this scenario is less than one. Overall, the CM in either direct fire or fire-and-forget modes displays a significant improvement in survivability over the HF equipped helicopter.

| | n | Mean | SD | Median | 95% CI of Mean |
|---|---|---|---|---|---|
| **HF Baseline** | 25 | 1.92 | 1.38 | 2.00 | 1.35 to 2.49 |
| **CM Direct Fire** | 25 | 1.04 | 0.45 | 1.00 | 0.85 to 1.22 |
| **CM Fire-and-Forget** | 25 | 0.72 | 0.46 | 1.00 | 0.53 to 0.90 |

Table 2. Descriptive Statistics for MOE 2 – Survivability.

The descriptive statistics highlight the improved survivability of the Longbow Apache when employing the CM. When comparing the HF Baseline to the CM Direct Fire case, there is a 46 percent improvement when employing the CM. The CM Fire-and-Forget case shows a 63 percent improvement in survivability over the baseline case. When examining the CM’s statistics, both the median and 95 percent CI point to expected loss rates within this deep attack scenario of one helicopter or less.

### 3. MOE 3 – Engagement

Engagement is defined as the average range of a shot, which resulted in an OPFOR kill.

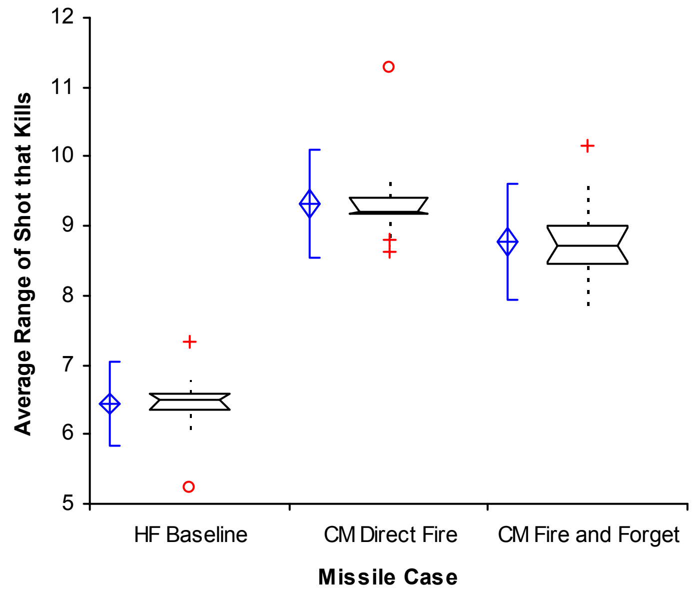



Figure 16. Boxplot MOE 3 – Engagement.

The significant increase in median kill range of the CM over the HF is highlighted with this measure. An increase in observed outliers is evident within this graph. This increase can be attributed to variance generated by helicopter to target intervisibility. This has little to do with the actual missile's performance, and more to do with helicopter position, flight profile, and atmospheric factors. There is a slight decrease in average range to kill between the CM Direct Fire and Fire-and-Forget cases. This is attributed to the greater requirement for HITL participation with the CM Fire-and-Forget model. The HITL aspect prevented engagement of targets by all aircraft simultaneously. To further clarify this aspect, the HITL model required the operator to identify the target and plot the round, then move on to the next target. The CM Direct

Fire case is not hampered by this process and benefits from target acquisition and engagement driven by the model's search and target acquisition algorithm only. The slight decrease in engagement range between the two CM cases was an expected outcome due to the HITL process. Overall, this graphical analysis of the CM shows a significant improvement in missile performance over the HF Baseline case.

| | n | Mean | SD | Median | 95% CI of Mean |
|---|---|---|---|---|---|
| **HF Baseline** | 25 | 6.44 | 0.37 | 6.49 | 6.29 to 6.59 |
| **CM Direct Fire** | 25 | 9.31 | 0.48 | 9.21 | 9.12 to 9.50 |
| **CM Fire-and-Forget** | 25 | 8.77 | 0.51 | 8.72 | 8.56 to 8.97 |

Table 3. Descriptive Statistics MOE 3 – Engagement.

The descriptive statistics show how an improved missile range was utilized when engaging enemy targets. The CM Direct Fire case shows a mean kill range increase of 2.87 km over the HF Baseline case. The extended kill range represents a 45 percent improvement, out of a possible 50 percent, over the HF. The CM Fire-and-Forget produces a 36 percent improvement over HF. In the deep attack scenario, there is 95 percent confidence that the CM, fired in direct fire mode, will achieve a kill at a range between 9.12 km and 9.50 km. During engagement, the HF missile used an average of 81 percent of its maximum range of 8 km. The CM used an average of 78 percent of its maximum range of 12 km. This fact has implications regarding the value of adding additional range capability to the CM. This analysis suggests adding additional range capability beyond 9.31 kilometers will result, on average, in less than

maximum utilization of the capability. This result could be due to the NOE flight profile used by helicopters. The combination of low altitude and rolling terrain create a difficult environment for the aircraft's optics or radar to achieve shooter to target intervisibility at long ranges.

### 4. Additional Data Requirements

Additional data requirements that support the evaluated MOEs are analyzed to provide added depth and benefit to the research.

#### *a. Kill Efficiency*

This metric is defined as the number of OPFOR killed divided by the number of missiles fired. This measure provides additional insight on lethality and is of significant interest to the warfighter. The raw data that were utilized for this calculation can be found in Appendix B.

| | HF Baseline | CM Direct Fire | CM Fire-and-Forget |
|---|---|---|---|
| Systems Killed | 20 | 25 | 28 |
| Missiles Fired | 34 | 32 | 46 |
| Kill Efficiency | 57.98% | 76.65% | 61.23% |

Table 4. Kill Efficiency.

The CM Direct Fire case shows an 18.67 percent improvement in kill efficiency over the HF. Again, the reduced improvement over HF seen in the CM Fire-and-Forget case can be attributed to the HITL. Due to the manual plotting requirement of the fire-and-forget model and the relative speed of the game there was a greater tendency with a HITL to fire upon the same target from more than one helicopter. This resulted in a greater number of missiles fired within the fire-and-forget case. Overall, this

scenario shows a significant improvement in kill efficiency when employing the CM. This improved efficiency is important to the warfighter, because it represents a reduction in resources required to accomplish this deep attack mission.

### b. Average OPFOR to Helicopter Kill Range

This metric is defined, as the average OPFOR system to aircraft kill range. This measure provides additional insight on the missile's impact on aircraft survivability.

| | HF Baseline | CM Direct Fire | CM Fire-and-Forget |
|---|---|---|---|
| Average Kill Range | 3.50 | 3.36 | 2.56 |

Table 5. Average OPFOR to Helicopter Kill Range.

The greater range to achieve a helicopter kill seen in the HF Baseline case can be attributed to the HF's reduced capability to destroy high threat OPFOR systems at an extended range. With these high threat systems still active as the ATKHC closes on the OPFOR position those systems prosecute their engagement at the maximum range possible. The most effective OPFOR weapon system employed in this scenario was the AT-11, which is an anti-tank missile fired from the T-72 tank. The progressively decreasing OPFOR to helicopter kill ranges seen in the two CM cases can be simply attributed to those systems that avoided being targeted by the CM at longer ranges. Those OPFOR systems maintained their concealed positions until the CM equipped Longbow closed within their range fan. This finding highlights the capability of the CM to destroy

high threat OPFOR systems at a greater standoff range enhancing overall survivability. It also depicts perceived lower threat targets as reason for leveraging the CM standoff by employing a limit of advance outside of the known threat systems maximum effective ranges.

#### *c. Average Minimum and Maximum Range to an OPFOR Kill*

This metric is defined as the average minimum and maximum range, which resulted in an OPFOR kill.

| | HF Baseline | CM Direct Fire | CM Fire-and-Forget |
|---|---|---|---|
| Minimum Range | 3.19 | 5.90 | 4.64 |
| Maximum Range | 7.97 | 11.93 | 11.95 |

Table 6. Average Minimum and Maximum Range to Kill.

This metric supports MOE 3 – Engagement. It shows a greater average minimum range to OPFOR kill or standoff for the CM as compared to the HF. The average maximum range to a kill is nearly equivalent to the maximum effective range for both the HF and the CM models. While an obvious increase in standoff is evident between the HF and CM, this increase in effectiveness can be attributed in part to the improved helicopter optics modeled on the CM equipped Longbow Apache. To further justify this position, the CM has already proved its increased standoff at ranges within the optics capability of the HF equipped helicopter. Therefore, the increased average maximum kill range beyond the HF 8 km limitation, must be partially attributed to optics.

## C. OPERATIONAL ANALYSIS

The operational analysis is divided into two primary sections. The first section is a quantitative approach used to plan attack helicopter operations called Engagement Area Calculus. The second section is a qualitative approach titled Employment Analysis.

### 1. Engagement Area Calculus

Engagement Area Calculus is a tool utilized by the tactical planner of attack aviation operations to determine how many aircraft and munitions will be needed to achieve the commander’s intent. This determination is largely based upon threat force size and the kill efficiency of the primary weapon system to be employed. In this scenario, the commander’s intent is to destroy the MRL battalion and its attached units, which equates to 70 percent of the OPFOR systems or 22 out of 32 systems destroyed. This analysis shows that when employing the CM versus the HF missile there is a significant difference in the resources required to accomplish this destruction mission. The CM Fire-and-Forget case will be analyzed, but will not be directly compared to the HF Baseline case in this portion of the analysis. The fire-and-forget case is intended to layer the CM’s capabilities for analysis and depict incremental improvement, but due to subtle differences in the execution of the scenario will not be used for an operational comparison. This operational analysis includes a comparison of the number of missiles required per missile type to achieve the commander’s intent for this deep attack mission (22/32 OPFOR killed), the expected number of kills for an ATKHC equipped with each missile type, and a

planning calculation focused on determining how many aircraft would be required to destroy all of the OPFOR vehicles in this scenario.

The number of missiles required to achieve the commander's intent is a critical consideration for the warfighter. This information supports both tactical and unit resource decisions. In this analysis, the commander's intent to destroy the equivalent of 70 percent of the OPFOR unit is a threshold. The objective of destroying 100 percent or 32 vehicles will also be analyzed.

| | HF Baseline | CM Direct Fire | CM Fire-and-Forget |
|---|---|---|---|
| Vehicles to Destroy | 22 | 22 | 22 |
| Missile Kill Efficiency | 57.98% | 76.65% | 61.23% |
| Number of Missiles Required | 38 | 29 | 36 |

Table 7. Missiles Required to Kill 70 Percent of OPFOR.

When comparing the HF Baseline against the CM Direct Fire case, the CM equipped ATKHC shows a 35% decrease in missiles required to achieve the commander's intent. This frees valuable resources to be applied elsewhere on the battlefield in support of the division commander's intent.

The expected number of kills for an ATKHC equipped with each missile type is a critical figure for the attack aviation planner. The next analysis differentiates the combat power of the ATKHC equipped by each of these missiles through highlighting potential combat power. This analysis examines the number of kills each company is expected to accomplish based on kill efficiency. These calculations are based upon an ATKHC of 8 aircraft equipped

with 16 missiles for a total of 128 missiles. These missiles represent 128 possible engagements for the ATKHC.

| | HF Baseline | CM Direct Fire | CM Fire-and-Forget |
|---|---|---|---|
| Number of Missiles Available | 128 | 128 | 128 |
| Missile Kill Efficiency | 57.98% | 76.65% | 61.23% |
| Expected Number of Kills | 74 | 98 | 78 |

Table 8. Expected Number of OPFOR Kills by the ATKHC.

Regardless of the missile type the ATKHC assigned the deep attack mission for this scenario was potentially capable of completing the stated commander’s intent 100 percent of the time. The ATKHC armed with the CM realized a 32 percent increase in combat power over the HF equipped company. In other words, the CM equipped unit has a higher expected number of kills than the HF unit.

The deep operations planner would certainly plan to achieve the threshold or commander’s intent of 70 percent of the OPFOR force, but many other variables must be considered in determining the resources required to accomplish the mission. The potential to destroy 100 percent of the OPFOR force is always desirable and must be considered by the planner. Moreover, potential loss of aircraft enroute to the ABF position must be considered during planning. While enroute losses go beyond the scope of this research, a safe assumption is that employing a unit capable of destroying 100 percent of the force has a higher probability of achieving the threshold of 70 percent, especially when considering the effects of unknown losses. To determine the resources required to accomplish the assigned mission, the number of OPFOR vehicles on the

battlefield was utilized to determine the friendly resources required. This analysis shows that less aircraft could be employed to accomplish this mission for both the HF and CM equipped units. Furthermore, when compared to the HF Baseline case, less CM equipped aircraft are required to accomplish this mission.

| | HF Baseline | CM Direct Fire | CM Fire-and-Forget |
|---|---|---|---|
| Vehicles to Destroy | 32 | 32 | 32 |
| Missile Kill Efficiency | 57.98% | 76.65% | 61.23% |
| Number of Missiles Required | 55 | 42 | 52 |
| Missiles per Aircraft | 16 | 16 | 16 |
| Number of Aircraft Required | 3.45 | 2.61 | 3.27 |

Table 9. Aircraft Required to Kill 100 Percent of the OPFOR.

This research employs a small sample size. Therefore the decrease in the number of aircraft required to accomplish this mission may not seem significant, but apply this improvement to a corps attack helicopter regiment, and the savings in resources are tremendous. Overall, 24 percent less CM equipped aircraft (HF Baseline versus CM Direct Fire) are required to accomplish this mission. When employing a corps attack regiment of 48 aircraft to accomplish a series of troop (company level) deep attack missions, this represents 12 less aircraft required. Those 12 aircraft can be employed by the corps commander to execute nearly 5 additional company sized deliberate attacks of this scenario’s magnitude.

### 2. Employment Analysis

This analysis is qualitative in nature and is based upon the author's interpretation of the data and observing the simulated battlefield during each of these cases.

By analyzing the CM capabilities in a layered manner, the contribution of each of these attributes can be better determined. Taking that into account, it is the range of the CM, not the fire-and-forget capability that is attributed with the improved performance of the missile during this research. The CM produced a 45 percent increase in average kill range over the HF. The increase in average number of kills from CM Direct Fire to CM Fire-and-Forget case was 12 percent and actually showed a slight decrease in average kill range of .54 km. The improvement in range directly impacted the survivability of the Longbow Apache. When armed with the CM, the survivability of the Longbow Apache increased by 46 percent. Survivability equates to preserving combat power for future engagements and is of the utmost importance to the attack planner. This analysis points to the range of the CM being the most significant and beneficial performance parameter to the warfighter.

The fire-and-forget capability of the CM may be both a boon and a bane to the ATKHC commander. The CM Fire-and-Forget case suggests that fire distribution or fire control is impacted by the use of CM. The potential exists to fire a fire-and-forget missile at a massed target and rely upon the missiles capabilities to provide the terminal guidance, inducing an increased possibility of multiple rounds impacting the same target. A capability to prevent this

from happening was not incorporated into the modeled CM. Therefore, this problem is partially due to the nature of the model and the simulation, but has some valid basis for concern in live employment. It is important to note that this is not a problem unique to CM. Fire distribution problems exist today in units employing the HF in both remote and direct fire modes, but the fire-and-forget technology has the potential to exacerbate this problem if not addressed early in the program. Overall, this is a concern to be addressed during requirements definition or concept exploration, but not one that can be determined to significantly degrade performance below that of HF.

The fire-and-forget aspect of the CM also may impact the commander's ability to retrieve battle damage assessment (BDA) at mission completion. This is largely due to the fact that CM can provide its own terminal guidance, and in high threat situations the Longbow Apache may employ the CM without eyes on the target through impact. Examples of this type of engagement could be firing on the move at air-defense threats enroute to the ABF position or firing into a deep attack EA utilizing target reference points without eyes on target. The latter could be due to intervisibility problems between shooter and target over the extremely long-range of the CM. Without an accurate BDA, it is extremely difficult for the unit commander to make a determination of mission success or the need for a re-attack. There are possible solutions to this problem such as utilizing a sensor other than the Longbow Apache to determine BDA. Within the context of this scenario, by employing the assets available to the attack helicopter battalion through the division and by utilizing

current tactics, techniques, and procedures used by the Longbow Apache Company, the potential of producing this result exists. Taking these unmitigated potential outcomes into account, the CM may produce; a more difficult environment for the battlefield commander to assess battle damage as compared to the current HF equipped ATKHC.

The last CM employment concern is the potential for fratricide with a missile of this design. The modeled missile is optimized for a deliberate attack behind the enemy front line trace. The capability to produce fratricide in this research was zero, because the fratricide was not enabled within the simulation and no friendly ground units were employed. In a direct fire mode the missile does not have any greater potential than the HF in inducing fratricide. When relying on the fire-and-forget capabilities of the missile in an environment where friendly ground forces are actively engaging OPFOR in a direct fire engagement or the close fight, the potential of fratricide may be increased. This is largely due to the fact the CM will provide its own terminal guidance to target. This could produce fratricide if friendly ground forces and OPFOR were engaged in close combat within the missile’s terminal footprint. This problem may be compounded by the fact that no current air-to-ground identification system exists that would prevent a fire-and-forget missile from mistakenly engaging a friendly ground element. With these unmitigated possibilities taken into account, an unknown, but potentially greater risk for fratricide exists with the CM over the HF.

The potential issues generated from this employment analysis may all be mitigated through new tactics and technology. Fire distribution and fire control will have to be addressed by the warfighter to provide a workable solution to this potential problem. The collection of the BDA can be solved through both a technological and tactical approach. New or existing sensors can be employed to gather the CM produced BDA or tactics, techniques, and procedures can be developed to retrieve this data with the ATKHC’s organic systems. Fratricide must be addressed and is the most difficult issue to mitigate. Potential solutions exist in technology and tactics, but in the end must be considered thoroughly before employing any fire-and-forget missile within the close fight.

In summary, taking these basic employment concerns outlined above into consideration, the benefits of extended range and greater lethality brought to the battlefield by CM far surpasses those of the HF missile. The statistical analysis and operational analysis of CM within this research scenario points to a tactical missile capability that will result in increased attack aviation survivability and significantly increased lethality. Conclusions and recommendations concerning these findings will be further discussed in the following chapter.

# VI. CONCLUSIONS AND RECOMMENDATIONS

## A. CONCLUSIONS

The CM shows significant improvement over the HF in lethality, survivability, and engagement within this Janus deep attack scenario. Furthermore, the increased capability of CM results in significant resource savings for the tactical commander. The resource savings represent combat power, which may be applied elsewhere in the battle space by the warfighter.

Table 10 depicts the answer to this thesis' primary research question, "Using the Janus Combat Model, which missile is the best operational alternative for Army Aviation and to what extent is it better?"

| | Improvement |
|---|---|
| MOE 1 - Lethality | 26% |
| MOE 2 - Survivability | 46% |
| MOE 3 - Engagement | 45% |

Table 10. Extent of CM Direct Fire Improvement Over HF.

Table 11 depicts the extent of resource savings realized through analysis of CM Direct Fire in the deep attack scenario.

| | Improvement |
|---|---|
| Number of Missiles Required for 70% Destruction Mission | 24% |
| ATKHC Expected Number of Kills | 32% |
| Number of Aircraft Required for 100% Destruction Mission | 24% |

Table 11. Extent of Resource Savings of CM Over HF.

## B. RECOMMENDATIONS

To enhance the validity of these results and add to the body of knowledge required to make a milestone decision for this missile, the CM model in Janus should be updated with classified data. Each scenario should be rerun to produce new data. This data would then provide more accurate insight regarding the use of the CM in an Army Aviation deep attack scenario.

Recommendations concerning the establishment of operational requirements and a baseline model for the CM include:

- For the capabilities of the CM to be fully realized by the legacy force, to include the Longbow Apache, the optics of these platforms will be the key limitation. Without benefit of improved optics both survivability and engagement will be equivalent to the HF baseline. Existing and future programs intending to employ this missile must consider this fact and the associated cost when designing new systems or enhancing existing platform optics.
- Fratricide prevention must be considered when determining the final requirement for fire-and-forget capabilities of the missile. The potential for fratricide could be reduced through hardware or software protocol designed into the missile. Employing fratricide-minimizing

techniques, tactics, and procedures solely would be an unacceptable solution to this potential problem, especially when considering the demands of the close fight.

The recommendations for the changes to the Janus database include:

- Develop a new scenario that incorporates a larger OPFOR and employs an Army aviation attack battalion to produce results meaningful to corps and division commanders.
- Increase the number of runs or eliminate the requirement for HITL to provide for a better analysis of variability.
- Employ the CM against an increasingly lethal OPFOR to include tanks employing reactive armor. Additionally, include OPFOR counter-measures to impact the effectiveness of the infrared, millimeter wave, and laser seeker capabilities employed by the CM.

## C. ANSWERS TO SUBSIDIARY RESEARCH QUESTIONS

**Utilizing tactics modified to take advantage of CM's new technological attributes, which missile is more effective and to what extent?**

The CM Direct Fire case shows significant improvement in all MOEs over the HF Baseline case. Clearly the CM in a direct fire mode outperformed the HF. With the addition layering of fire-and-forget technology over the direct fire case, the improvement over the HF shows additional increase in missile effectiveness in all but MOE 3 - Engagement. Again, this conclusion must be tempered with the explanation of the added HITL requirement for the CM Fire-and-Forget case. The extent of this increase in missile performance is displayed in Table 12.

| | Improvement |
|---|---|
| MOE 1 - Lethality | 42% |
| MOE 2 - Survivability | 63% |
| MOE 3 - Engagement | 36% |

Table 12. CM Fire-and-Forget Improvement Over HF.

**What tactical benefits does the CM and attack aviation combination bring to the battlefield?**

The single greatest advantage to attack aviation brought to the battlefield by the CM is its increased standoff or engagement range. This increased capability contributes greatly to the survivability of the attack helicopter and in the end preserves a greater amount of combat power than the HF for future employment. This ability to preserve combat power coupled with the increased lethality of the missile makes it an optimal primary missile for Army attack aviation.

**How can Janus results be useful and its results meaningful to a Program Manager (PM)?**

How meaningful the results produced by Janus is largely dependent upon the research analyst's thoroughness in developing the applied scenario, weapon model, and analytical framework for the study. Before the results should be utilized by the PM he must fully understand the assumptions utilized by the research analyst during the development of the scenario and model, as well as the basic Janus Combat Model limitations. The CM modeled within this study employs an assumed probability of kill for the concept missile. A decrease in this assumed probability could result in the baseline alternative being the best solution to this requirement. This assumption and several

other critical design specifications greatly affect the final outcome of this research. Understanding these design assumptions is critical to understanding this study. The database values, which support the design assumptions, are contained within the Appendix A. If the results derived from Janus are used without this foreknowledge, the PM may be making a decision based upon data, which has been synthesized in a manner that does not adequately support his program's needs or the overall decision-making process. With careful consideration of all of these factors the results of a study employing Janus may be used in support of program decisions.

Janus results can be useful to the PM throughout the life cycle of a system, but it is particularly useful during requirements development and concept exploration phases. One of the PM's greatest concerns is resolving system requirements when the design required to achieve desired performance is not feasible in terms of cost, performance, or schedule. [Ref. 18] Since Janus is accessible at most TRADOC facilities and many acquisition centers, it is an effective means to determine the most cost-effective requirements for a given concept. Janus also is a highly beneficial bridging tool between the user representative and the project office. Janus can aid the PM in his collaborative efforts to develop team understanding of the costs associated with desired capability. Janus allows the user representative in concert with the program office to develop the best solution for the warfighter, while considering cost through capability tradeoffs within a given scenario.

Janus can be a key tool to support daily operations in any acquisition project office. The ability for a PM to turn to his lead engineer and have a scenario quickly run with a pre-defined model to see the effects of new or removed capabilities can be a powerful tool. This capability can provide additional justification at short notice for the expenditure, acquisition or defense of project funds.

## D. SUGGESTED AREAS OF FURTHER RESEARCH

The following are potential areas of future research based upon the findings of this study:

- Evaluate the cost-effectiveness of the key performance parameters and other operational requirements stated for this missile. How much does the additional lethality, survivability, or engagement capability cost?
- Study the effects of the CM on force effectiveness on a larger scale. Develop a new scenario, which incorporates a larger OPFOR and employs an Army attack battalion to produce results meaningful to corps and division commanders. How much more combat effectiveness does the CM and attack aviation combination bring to the battle as compared to existing systems?
- Examine the effects of the fire-and-forget technology employed with this missile in the close fight. The intent would be to analyze the need for a design requirement, which would minimize fratricide when employing the CM from attack aviation.

# APPENDIX A. SYSTEMS DATABASE

This appendix outlines the system specifications utilized to model the entities within Scenario 235, 245, and 255. This appendix provides data for both friendly (Blue forces) and OPFOR systems (Red forces).

## A. FRIENDLY SYSTEMS

FRIENDLY SYSTEMS GENERAL CHARACTERISTICS

| Sys Num | Sys Name | Max Rd Speed (Km/hr) | Max Visbl (Km) | Wpn Rng (Km) | Sens Hght (m) | Crew Size | Elemt Space (m) | Chem Xmit Fctr | Gra Sym | Cls Sym | Host Cap |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 15 | AH-64DCM | 200 | 20.0 | 12.0 | 4 | 2 | 100 | 1.00 | 44 | 126 | 0 |
| 05 | AH-64D | 200 | 9.0 | 8.0 | 4 | 2 | 100 | 1.00 | 44 | 126 | 0 |

FRIENDLY SYSTEM FUNCTIONAL CHARACTERISTICS

| Sys Num | Sys Name | Lsr Dsg | Min Dsp | Eng Typ | Fir Cat | Fly Typ | Log Typ | Mov Typ | Rdr Typ | Smk Dsp | Srv Typ | Swm Typ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15 | AH-64DCM | 1 | | | 3 | 64 | | 4 | | | | |
| 05 | AH-64D | 1 | | | 3 | 64 | | 4 | | | | |

FRIENDLY SYSTEMS DETECTION DATA

| | | DETECT Dimensions (Meters) | | | SENSORS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Sys Num | Sys Name | Lngth | Width | Hght | Prim | Alt | Defil | Popup | BCIS Type | BCIS Func |
| 15 | AH-64DCM | 15.84 | 2.03 | 3.84 | 12 | 18 | 12 | | | |
| 05 | AH-64D | 15.84 | 2.03 | 3.84 | 12 | 18 | | | | |

CYCLES per MILLIRADIAN versus TEMPERATURE or CONTRAST

Sensor Number: 12

| Pair | Cycles | TMP/CON | Pair | Cycles | TMP/CON |
|---|---|---|---|---|---|
| 1 | 1.179 | 0.009 | 11 | 7.948 | 0.361 |
| 2 | 1.783 | 0.013 | 12 | 8.477 | 0.522 |
| 3 | 2.471 | 0.019 | 13 | 8.87 | 0.756 |
| 4 | 3.237 | 0.027 | 14 | 9.107 | 1.093 |
| 5 | 4.005 | 0.039 | 15 | 9.332 | 1.580 |
| 6 | 4.754 | 0.057 | 16 | 9.545 | 2.286 |
| 7 | 5.470 | 0.083 | 17 | 9.745 | 3.306 |
| 8 | 6.145 | 0.119 | 18 | 9.937 | 4.781 |
| 9 | 6.782 | 0.173 | 19 | 10.117 | 6.914 |
| 10 | 7.384 | 0.250 | 20 | 10.290 | 10.000 |

OPTICAL AND THERMAL CONTRAST DATA

| | | Thermal Contrast | |
|---|---|---|---|
| Sys Num | Optical Contrast | Exposed | Defilade |
| 15 | 0.200 | 3.418 | 3.418 |
| 05 | 0.200 | 3.418 | 3.418 |

SENSOR FIELD of VIEW (FOV) and BAND

| | FOV-(Degrees) | | | | |
|---|---|---|---|---|---|
| Sensor Num | Narrow | Wide | Narrow-to-Wide Factor | Spectral Band | (1,2 = Optical 3,4 = Thermal) |
| 12 | 3.00 | 10.05 | 0.29851 | 4 | |
| 12 | 3.00 | 10.05 | 0.29851 | 4 | |


CYCLES per MILLIRADIAN versus TEMPERATURE or CONTRAST

Sensor Number: 12

| Pair | Cycles | TMP/CON | Pair | Cycles | TMP/CON |
|---|---|---|---|---|---|
| 1 | 1.179 | 0.009 | 11 | 7.948 | 0.361 |
| 2 | 1.783 | 0.013 | 12 | 8.477 | 0.522 |
| 3 | 2.471 | 0.019 | 13 | 8.87 | 0.756 |
| 4 | 3.237 | 0.027 | 14 | 9.107 | 1.093 |
| 5 | 4.005 | 0.039 | 15 | 9.332 | 1.580 |
| 6 | 4.754 | 0.057 | 16 | 9.545 | 2.286 |
| 7 | 5.470 | 0.083 | 17 | 9.745 | 3.306 |
| 8 | 6.145 | 0.119 | 18 | 9.937 | 4.781 |
| 9 | 6.782 | 0.173 | 19 | 10.117 | 6.914 |
| 10 | 7.384 | 0.250 | 20 | 10.290 | 10.000 |

WEAPONS/ORDNANCE for Friendly system AH-64D

Wpn/Ord Number

| Relative (1-15) | Absolute (1-250) | Wpn/Ord Name | Basic Load | Upload Time (Minutes) | Rel Wpn/Ord to use if Ammo Expended (1-15) |
|---|---|---|---|---|---|
| 6 | 14 | Wpn 14 | 16 | 0.0 | |

WEAPONS/ORDNANCE for Friendly system CM

Wpn/Ord Number

| Relative (1-15) | Absolute (1-250) | Wpn/Ord Name | Basic Load | Upload Time (Minutes) | Rel Wpn/Ord to use if Ammo Expended (1-15) |
|---|---|---|---|---|---|
| 6 | 28 | CM DF | 16 | | |

Friendly WEAPON/ROUND CHARACTERISTICS

| Wpn Num | Wpn Name | Lay Time (Sec) | Aim Time (Sec) | Reload Time (Sec) | Rnds / Trggr Pull | Trggr Pulls / Reload | Round Speed (Km/Sec) | Min. SSKP |
|---|---|---|---|---|---|---|---|---|
| 14 | Wpn 14 | 6.0 | 6.0 | 120.0 | 1 | 16 | 0.400 | 5 |
| 28 | CM DF | 6.0 | 6.0 | 60.0 | 1 | 16 | 0.400 | 5 |

Friendly WEAPON/ROUND GUIDANCE DATA

Fire on: 0 = Yes, no restrictions. 1 = Stop, can move before impact

the Move: 3 = Reduce speed to fire. 2 = Stop, only move after impact

| Wpn Num | Wpn Name | Guidance Mode | Fire on the Move | On-Board Sensor | Critical Altitude (meters) |
|---|---|---|---|---|---|
| 14 | Wpn 14 | 2 | 2 | | |
| 28 | CM DF | | 1 | 2 | |

HIT and KILL DATA SET Numbers for Friendly Weapon Wpn 14

| RED Target Sys Num | RED Target Sys Name | PH Data Set | PK Data Set |
|---|---|---|---|
| 389 | T72 | 549 | 549 |
| 358 | ZSU-23-4 | 549 | 549 |
| 95 | BM21 | 549 | 549 |

HIT and KILL DATA SET Numbers for Friendly Weapon CM DF

| RED Target Sys Num | RED Target Sys Name | PH Data Set | PK Data Set |
|---|---|---|---|
| 389 | T72 | 100 | 100 |
| 358 | ZSU-23-4 | 100 | 100 |
| 95 | BM21 | 100 | 100 |

PROBABILITY of HIT Data Set: 0549

| Range(m)--> | 650 | 2500 | 4000 | 5500 | 8000 |
|---|---|---|---|---|---|
| Posture: | | | | | |
| SSDF | 0.89420 | 0.91360 | 0.89060 | 0.80500 | 0.63660 |
| SSDH | 0.89550 | 0.91390 | 0.89340 | 0.80050 | 0.60170 |
| SSEF | 0.89420 | 0.91360 | 0.89060 | 0.80500 | 0.63660 |
| SSEH | 0.89550 | 0.91390 | 0.89340 | 0.80050 | 0.60170 |
| SMDF (not used) | 0.89420 | 0.94000 | 0.94000 | 0.94000 | 0.94000 |
| SMDH (not used) | 0.89550 | 0.91390 | 0.89340 | 0.80050 | 0.60170 |
| SMEF | 0.89420 | 0.94000 | 0.94000 | 0.94000 | 0.94000 |
| SMEH | 0.89550 | 0.91390 | 0.89340 | 0.80050 | 0.60170 |
| MSDF | | | | | |
| MSDH | | | | | |
| MSEF | | | | | |
| MSEH | | | | | |
| MMDF (not used) | | | | | |
| MMDH (not used) | | | | | |
| MMEF | | | | | |
| MMEH | | | | | |

PROBABILITY of HIT Data Set: 0100

| Range(m)--> | 500 | 3000 | 6000 | 9000 | 12000 |
|---|---|---|---|---|---|
| Posture: | | | | | |
| SSDF | 0.94000 | 0.94000 | 0.94000 | 0.94000 | 0.94000 |
| SSDH | 0.94000 | 0.94000 | 0.94000 | 0.94000 | 0.94000 |
| SSEF | 0.94000 | 0.94000 | 0.94000 | 0.94000 | 0.94000 |
| SSEH | 0.94000 | 0.94000 | 0.94000 | 0.94000 | 0.94000 |
| SMDF (not used) | 0.94000 | 0.94000 | 0.94000 | 0.94000 | 0.94000 |
| SMDH (not used) | 0.94000 | 0.94000 | 0.94000 | 0.94000 | 0.94000 |
| SMEF | 0.94000 | 0.94000 | 0.94000 | 0.94000 | 0.94000 |
| SMEH | 0.94000 | 0.94000 | 0.94000 | 0.94000 | 0.94000 |
| MSDF | | | | | |
| MSDH | | | | | |
| MSEF | | | | | |
| MSEH | | | | | |
| MMDF (not used) | | | | | |
| MMDH (not used) | | | | | |
| MMEF | | | | | |
| MMEH | | | | | |

PROBABILITY of KILL Data Set: 0549

| Range(m)--> | 650 | 2500 | 4000 | 5500 | 8000 |
|---|---|---|---|---|---|
| Posture: | | | | | |
| M/ DF | 0.74800 | 0.76970 | 0.73840 | 0.69150 | 0.66640 |
| M/ DH | 0.66580 | 0.69280 | 0.68680 | 0.65860 | 0.61980 |
| M/ EF | 0.74800 | 0.76970 | 0.73840 | 0.69150 | 0.66640 |
| M/ EH | 0.66580 | 0.69280 | 0.68680 | 0.65860 | 0.61980 |

PROBABILITY of KILL Data Set: 0100

| Range(m)--> | 500 | 3000 | 6000 | 9000 | 12000 |
|---|---|---|---|---|---|
| Posture: | | | | | |
| M/ DF | 0.80000 | 0.80000 | 0.80000 | 0.80000 | 0.80000 |
| M/ DH | 0.80000 | 0.80000 | 0.80000 | 0.80000 | 0.80000 |
| M/ EF | 0.80000 | 0.80000 | 0.80000 | 0.80000 | 0.80000 |
| M/ EH | 0.80000 | 0.80000 | 0.80000 | 0.80000 | 0.80000 |

## B. OPFOR SYSTEMS

OPFOR SYSTEMS GENERAL CHARACTERISTICS

| Sys Num | Sys Name | Max Rd Speed (Km/hr) | Max Visbl (Km) | Wpn Rng (Km) | Sens Hght (m) | Crew Size | Elemt Space (m) | Chem Xmit Fctr | Gra Sym | Cls Sym | Host Cap |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 389 | T72 | 60 | 6.0 | 5.0 | 2 | 3 | 50 | 1.00 | 66 | 122 | |
| 358 | ZSU-23-4 | 50 | 6.0 | 3.0 | 10 | 4 | 500 | 0.80 | 109 | 123 | |
| 95 | BM21 | 60 | 3.0 | | 3 | 3 | 100 | 1.00 | 116 | 125 | |

OPFOR SYSTEM FUNCTIONAL CHARACTERISTICS

| Sys Num | Sys Name | Lsr Dsg | Min Dsp | Eng Typ | Fir Cat | Fly Typ | Log Typ | Mov Typ | Rdr Typ | Smk Dsp | Srv Typ | Swm Typ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 389 | T72 | | | 3 | 1 | | | 2 | | 3 | | |
| 358 | ZSU-23-4 | | | 4 | 1 | | | 2 | 19 | | | |
| 95 | BM21 | | | 5 | 2 | | | 1 | | | | |

OPFOR SYSTEMS DETECTION DATA

| | | DETECT Dimensions (Meters) | | | SENSORS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Sys Num | Sys Name | Lngth | Width | Hght | Prim | Alt | Defil | Popup | BCIS Type | BCIS Func |
| 389 | T72 | 5.48 | 3.15 | 2.25 | 23 | 37 | 17 | 1 | | |
| 358 | ZSU-23-4 | 6.54 | 2.25 | 2.95 | 7 | | 17 | | | |
| 95 | BM21 | 7.42 | 2.50 | 3.05 | 1 | | 1 | | | |

OPTICAL AND THERMAL CONTRAST DATA

| | | Thermal Contrast | |
|---|---|---|---|
| Sys Num | Optical Contrast | Exposed | Defilade |
| 389 | 0.360 | 2.000 | 0.500 |
| 358 | 0.350 | 4.084 | 1.000 |
| 95 | 0.360 | 2.000 | 0.500 |

SENSOR FIELD of VIEW (FOV) and BAND

| Sensor Number | FOV-(Degrees) Narrow | Wide | Narrow-to-Wide Factor | Specral Band | (1,2 = Optical 3,4 = Thermal) |
|---|---|---|---|---|---|
| 23 | 15.00 | | | 1 | |
| 7 | 3.60 | 13.30 | 0.26670 | 4 | |
| 1 | 10.00 | | | 1 | |

CYCLES per MILLIRADIAN versus TEMPERATURE or CONTRAST

Sensor Number: 23

| Pair | Cycles | TMP/CON | Pair | Cycles | TMP/CON |
|---|---|---|---|---|---|
| 1 | 0.000 | 0.020 | 11 | 10.620 | 0.400 |
| 2 | 3.816 | 0.030 | 12 | 10.950 | 0.450 |
| 3 | 4.776 | 0.040 | 13 | 11.256 | 0.500 |
| 4 | 5.400 | 0.050 | 14 | 11.544 | 0.550 |
| 5 | 7.128 | 0.100 | 15 | 11.814 | 0.600 |
| 6 | 8.112 | 0.150 | 16 | 12.072 | 0.650 |
| 7 | 8.814 | 0.200 | 17 | 12.318 | 0.700 |
| 8 | 9.378 | 0.250 | 18 | 12.792 | 0.800 |
| 9 | 9.846 | 0.300 | 19 | 13.248 | 0.900 |
| 10 | 10.254 | 0.350 | 20 | 13.686 | 1.000 |

CYCLES per MILLIRADIAN versus TEMPERATURE or CONTRAST

Sensor Number: 07

| Pair | Cycles | TMP/CON | Pair | Cycles | TMP/CON |
|---|---|---|---|---|---|
| 1 | 0.969 | 0.010 | 11 | 6.054 | 0.367 |
| 2 | 1.446 | 0.014 | 12 | 6.462 | 0.527 |
| 3 | 1.974 | 0.020 | 13 | 6.849 | 0.758 |
| 4 | 2.540 | 0.029 | 14 | 7.217 | 1.089 |
| 5 | 3.098 | 0.042 | 15 | 7.567 | 1.565 |
| 6 | 3.650 | 0.060 | 16 | 7.772 | 2.249 |
| 7 | 4.185 | 0.086 | 17 | 7.942 | 3.231 |
| 8 | 4.688 | 0.124 | 18 | 8.108 | 4.643 |
| 9 | 5.164 | 0.178 | 19 | 8.261 | 6.671 |
| 10 | 5.621 | 0.255 | 20 | 8.413 | 9.586 |

CYCLES per MILLIRADIAN versus TEMPERATURE or CONTRAST

Sensor Number: 01

| Pair | Cycles | TMP/CON | Pair | Cycles | TMP/CON |
|---|---|---|---|---|---|
| 1 | 0.000 | 0.020 | 11 | 1.787 | 0.400 |
| 2 | 0.650 | 0.030 | 12 | 1.842 | 0.450 |
| 3 | 0.810 | 0.040 | 13 | 1.893 | 0.500 |
| 4 | 0.914 | 0.050 | 14 | 1.941 | 0.550 |
| 5 | 1.204 | 0.100 | 15 | 1.986 | 0.600 |
| 6 | 1.367 | 0.150 | 16 | 2.029 | 0.650 |
| 7 | 1.485 | 0.200 | 17 | 2.071 | 0.700 |
| 8 | 1.579 | 0.250 | 18 | 2.150 | 0.800 |
| 9 | 1.657 | 0.300 | 19 | 2.226 | 0.900 |
| 10 | 1.726 | 0.350 | 20 | 2.299 | 1.000 |

WEAPONS/ORDNANCE for OPFOR system T72

Wpn/Ord Number

| Relative (1-15) | Absolute (1-250) | Wpn/Ord Name | Basic Load | Upload Time (Minutes) | Rel Wpn/Ord to use if Ammo Expended (1-15) |
|---|---|---|---|---|---|
| 10 | 378 | AT-11 | 6 | 2.0 | 13 |
| 13 | 381 | 125APFSDS | 12 | 2.0 | 10 |

WEAPONS/ORDNANCE for OPFOR system ZSU-23-4

Wpn/Ord Number

| Relative (1-15) | Absolute (1-250) | Wpn/Ord Name | Basic Load | Upload Time (Minutes) | Rel Wpn/Ord to use if Ammo Expended (1-15) |
|---|---|---|---|---|---|
| 2 | 392 | HE-T 23mm | 1500 | 2.0 | 3 |
| 3 | 393 | API-T 23 mm | 500 | 2.0 | 2 |

OPFOR WEAPON/ROUND CHARACTERISTICS

| Wpn Num | Wpn Name | Lay Time (Sec) | Aim Time (Sec) | Reload Time (Sec) | Rnds / Trggr Pull | Trggr Pulls / Reload | Round Speed (Km/Sec) | Min. SSKP |
|---|---|---|---|---|---|---|---|---|
| 378 | AT-11 | 6.9 | 3.0 | 10.0 | 1 | 7 | 0.350 | 5 |
| 381 | 125APFSDS | 9.0 | 4.5 | 10.0 | 1 | 1 | 1.700 | 5 |
| 392 | HE-T 23mm | 8.3 | 2.7 | 120 | 20 | 25 | 0.89 | 5 |
| 393 | API-T 23 mm | 8.3 | 2.7 | 120 | 10 | 25 | 1 | 5 |

OPFOR WEAPON/ROUND GUIDANCE DATA

Fire on: 0 = Yes, no restrictions. 1 = Stop, can move before impact
the Move: 3 = Reduce speed to fire. 2 = Stop, only move after impact

| Wpn Num | Wpn Name | Guidance Mode | Fire on the Move | On-Board Sensor | Critical Altitude (meters) |
|---|---|---|---|---|---|
| 378 | AT-11 | 2 | 1 | | |
| 381 | 125APFSDS | | | | |
| 392 | HE-T 23mm | | 1 | | |
| 393 | API-T 23 mm | | 1 | | |

HIT and KILL DATA SET Numbers for OPFOR Weapon AT-11

| BLUE Target Sys Num | BLUE Target Sys Name | PH Data Set | PK Data Set |
|---|---|---|---|
| 5 | AH-64D | 741 | 741 |
| 15 | AH-64DCM | 741 | 741 |

HIT and KILL DATA SET Numbers for OPFOR Weapon 125APFDSDS

| BLUE Target Sys Num | BLUE Target Sys Name | PH Data Set | PK Data Set |
|---|---|---|---|
| 5 | AH-64D | 722 | 722 |
| 15 | AH-64DCM | 722 | 722 |

HIT and KILL DATA SET Numbers for OPFOR Weapon HE-T 23mm

| BLUE Target Sys Num | BLUE Target Sys Name | PH Data Set | PK Data Set |
|---|---|---|---|
| 5 | AH-64D | 649 | 649 |
| 15 | AH-64DCM | 649 | 649 |

HIT and KILL DATA SET Numbers for OPFOR Weapon API-T 23mm

| BLUE Target Sys Num | BLUE Target Sys Name | PH Data Set | PK Data Set |
|---|---|---|---|
| 5 | AH-64D | 645 | 645 |
| 15 | AH-64DCM | 645 | 645 |

PROBABILITY of HIT Data Set: 741

| Range(m)--> | 250 | 1375 | 2250 | 3125 | 5000 |
|---|---|---|---|---|---|
| Posture: | | | | | |
| SSDF | 0.95000 | 0.95000 | 0.95000 | 0.95000 | 0.95000 |
| SSDH | 0.95000 | 0.95000 | 0.95000 | 0.95000 | 0.95000 |
| SSEF | 0.95000 | 0.95000 | 0.95000 | 0.95000 | 0.95000 |
| SSEH | 0.95000 | 0.95000 | 0.95000 | 0.95000 | 0.95000 |
| SMDF (not used) | 0.95000 | 0.95000 | 0.95000 | 0.95000 | 0.95000 |
| SMDH (not used) | 0.95000 | 0.95000 | 0.95000 | 0.95000 | 0.95000 |
| SMEF | 0.95000 | 0.95000 | 0.95000 | 0.95000 | 0.95000 |
| SMEH | 0.95000 | 0.95000 | 0.95000 | 0.95000 | 0.95000 |
| MSDF | | | | | |
| MSDH | | | | | |
| MSEF | | | | | |
| MSEH | | | | | |
| MMDF (not used) | | | | | |
| MMDH (not used) | | | | | |
| MMEF | | | | | |
| MMEH | | | | | |

PROBABILITY of HIT Data Set: 722

| Range(m)--> | 1 | 1075 | 2050 | 3025 | 4000 |
|---|---|---|---|---|---|
| Posture: | | | | | |
| SSDF | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 |
| SSDH | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 |
| SSEF | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 |
| SSEH | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 |
| SMDF (not used) | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 |
| SMDH (not used) | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 |
| SMEF | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 |
| SMEH | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 |
| MSDF | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 |
| MSDH | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 |
| MSEF | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 |
| MSEH | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 |
| MMDF (not used) | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 |
| MMDH (not used) | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 |
| MMEF | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 |
| MMEH | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 |

PROBABILITY of HIT Data Set: 649

| Range(m)--> | 1 | 1000 | 1500 | 2000 | 2500 |
|---|---|---|---|---|---|
| Posture: | | | | | |
| SSDF | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 |
| SSDH | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 |
| SSEF | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 |
| SSEH | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 |
| SMDF (not used) | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 |
| SMDH (not used) | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 |
| SMEF | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 |
| SMEH | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 |
| MSDF | | | | | |
| MSDH | | | | | |
| MSEF | | | | | |
| MSEH | | | | | |
| MMDF (not used) | | | | | |
| MMDH (not used) | | | | | |
| MMEF | | | | | |
| MMEH | | | | | |

PROBABILITY of HIT Data Set: 645

| Range(m)--> | 1 | 1125 | 1750 | 2375 | 3000 |
|---|---|---|---|---|---|
| Posture: | | | | | |
| SSDF | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 |
| SSDH | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 |
| SSEF | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 |
| SSEH | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 |
| SMDF (not used) | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 |
| SMDH (not used) | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 |
| SMEF | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 |
| SMEH | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 |
| MSDF | | | | | |
| MSDH | | | | | |
| MSEF | | | | | |
| MSEH | | | | | |
| MMDF (not used) | | | | | |
| MMDH (not used) | | | | | |
| MMEF | | | | | |
| MMEH | | | | | |

PROBABILITY of KILL Data Set: 0741

| Range(m)--> | 250 | 1375 | 2250 | 3125 | 5000 |
|---|---|---|---|---|---|
| Posture: | | | | | |
| MOBDF | 0.67010 | 0.66940 | 0.66950 | 0.66990 | 0.66860 |
| MOBDH | 0.61010 | 0.60930 | 0.60950 | 0.60990 | 0.60860 |
| MOBEF | 0.67010 | 0.66940 | 0.66950 | 0.66990 | 0.66860 |
| MOBEH | 0.61010 | 0.60930 | 0.60950 | 0.60990 | 0.60860 |
| FRPDF | 0.67010 | 0.66940 | 0.66950 | 0.66990 | 0.66860 |
| FRPDH | 0.61010 | 0.60930 | 0.60950 | 0.60990 | 0.60860 |
| FRPEF | 0.67010 | 0.66940 | 0.66950 | 0.66990 | 0.66860 |
| FRPEH | 0.61010 | 0.60930 | 0.60950 | 0.60990 | 0.60860 |
| M/ DF | 0.67010 | 0.66940 | 0.66950 | 0.66990 | 0.66860 |
| M/ DH | 0.61010 | 0.60930 | 0.60950 | 0.60990 | 0.60860 |
| M/ EF | 0.67010 | 0.66940 | 0.66950 | 0.66990 | 0.66860 |
| M/ EH | 0.61010 | 0.60930 | 0.60950 | 0.60990 | 0.60860 |
| KK DF | 0.67010 | 0.66940 | 0.66950 | 0.66990 | 0.66860 |
| KK DH | 0.61010 | 0.60930 | 0.60950 | 0.60990 | 0.60860 |
| KK EF | 0.67010 | 0.66940 | 0.66950 | 0.66990 | 0.66860 |
| KK EH | 0.61010 | 0.60930 | 0.60950 | 0.60990 | 0.60860 |

PROBABILITY of KILL Data Set: 0722

| Range(m)--> | 1 | 1375 | 2250 | 3125 | 4000 |
|---|---|---|---|---|---|
| Posture: | | | | | |
| MOBDF | | | | | |
| MOBDH | | | | | |
| MOBEF | | | | | |
| MOBEH | | | | | |
| FRPDF | | | | | |
| FRPDH | | | | | |
| FRPEF | | | | | |
| FRPEH | | | | | |
| M/ DF | 0.97380 | 0.64230 | 0.38860 | 0.24300 | 0.16060 |
| M/ DH | 0.96410 | 0.58530 | 0.34010 | 0.20900 | 0.13680 |
| M/ EF | 0.97380 | 0.64230 | 0.38860 | 0.24300 | 0.16060 |
| M/ EH | 0.96410 | 0.58530 | 0.34010 | 0.20900 | 0.13680 |
| KK DF | | | | | |
| KK DH | | | | | |
| KK EF | | | | | |
| KK EH | | | | | |

PROBABILITY of KILL Data Set: 649

| Range(m)--> | 1 | 1000 | 1500 | 2000 | 2500 |
|---|---|---|---|---|---|
| Posture: | | | | | |
| MOBDF | 0.01050 | 0.00270 | 0.00120 | 0.00070 | 0.00040 |
| MOBDH | 0.00860 | 0.00220 | 0.00100 | 0.00060 | 0.00040 |
| MOBEF | 0.01050 | 0.00270 | 0.00120 | 0.00070 | 0.00040 |
| MOBEH | 0.00860 | 0.00220 | 0.00100 | 0.00060 | 0.00040 |
| FRPDF | 0.01260 | 0.00330 | 0.00150 | 0.00090 | 0.00050 |
| FRPDH | 0.01050 | 0.00280 | 0.00120 | 0.00070 | 0.00050 |
| FRPEF | 0.01260 | 0.00330 | 0.00150 | 0.00090 | 0.00050 |
| FRPEH | 0.01050 | 0.00280 | 0.00120 | 0.00070 | 0.00050 |
| M/ DF | 0.04420 | 0.01750 | 0.00900 | 0.00540 | 0.00360 |
| M/ DH | 0.03950 | 0.01530 | 0.00790 | 0.00470 | 0.00310 |
| M/ EF | 0.04420 | 0.01750 | 0.00900 | 0.00540 | 0.00360 |
| M/ EH | 0.03950 | 0.01530 | 0.00790 | 0.00470 | 0.00310 |
| KK DF | | | | | |
| KK DH | | | | | |
| KK EF | | | | | |
| KK EH | | | | | |

PROBABILITY of KILL Data Set: 645

| Range(m)- | 1 | 1125 | 1750 | 2375 | 3000 |
|---|---|---|---|---|---|
| Posture: | | | | | |
| MOBDF | 0.03520 | 0.00720 | 0.00290 | 0.00150 | 0.00090 |
| MOBDH | 0.02930 | 0.00590 | 0.00230 | 0.00120 | 0.00070 |
| MOBEF | 0.03520 | 0.00720 | 0.00290 | 0.00150 | 0.00090 |
| MOBEH | 0.02930 | 0.00590 | 0.00230 | 0.00120 | 0.00070 |
| FRPDF | 0.04160 | 0.00870 | 0.00350 | 0.00180 | 0.00110 |
| FRPDH | 0.03520 | 0.00730 | 0.00290 | 0.00150 | 0.00090 |
| FRPEF | 0.04160 | 0.00870 | 0.00350 | 0.00180 | 0.00110 |
| FRPEH | 0.03520 | 0.00730 | 0.00290 | 0.00150 | 0.00090 |
| M/ DF | 0.18390 | 0.05730 | 0.02520 | 0.01360 | 0.00840 |
| M/ DH | 0.16320 | 0.04960 | 0.02170 | 0.01170 | 0.00720 |
| M/ EF | 0.18390 | 0.05730 | 0.02520 | 0.01360 | 0.00840 |
| M/ EH | 0.16320 | 0.04960 | 0.02170 | 0.01170 | 0.00720 |
| KK DF | | | | | |
| KK DH | | | | | |
| KK EF | | | | | |
| KK EH | | | | | |

# APPENDIX B. DATA

This appendix provides the raw data generated by the Janus post processor reports from scenarios 235 (CM Fire-and-Forget), 245 (HF Baseline), and 255 (CM Direct Fire). The data is provided in two formats. First, a synthesized format is presented, which was utilized with the Analyze-it Excel add-in for the studies primary statistical analysis. Second, it is provided in a raw data format as it was taken from the Janus reports. This appendix provides data for both friendly (Blue forces) and OPFOR systems (Red forces).

## A. SYNTHESIZED DATA

| MOE 1 | MOE 1 - Lethality | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | HF Baseline | | | CM Direct Fire | | | CM Fire and Forget | | |
| Run | Systems Killed | Missiles Fired | Kill Efficiency | Systems Killed | Missiles Fired | Kill Efficiency | Systems Killed | Missiles Fired | Kill Efficiency |
| 1 | 22 | 26 | 84.62% | 23 | 31 | 74.19% | 28 | 51 | 54.90% |
| 2 | 18 | 36 | 50.00% | 25 | 34 | 73.53% | 30 | 44 | 68.18% |
| 3 | 20 | 34 | 58.82% | 26 | 30 | 86.67% | 28 | 48 | 58.33% |
| 4 | 17 | 30 | 56.67% | 24 | 29 | 82.76% | 27 | 56 | 48.21% |
| 5 | 17 | 41 | 41.46% | 24 | 29 | 82.76% | 29 | 48 | 60.42% |
| 6 | 19 | 34 | 55.88% | 25 | 29 | 86.21% | 28 | 45 | 62.22% |
| 7 | 14 | 29 | 48.28% | 25 | 31 | 80.65% | 28 | 53 | 52.83% |
| 8 | 24 | 39 | 61.54% | 22 | 27 | 81.48% | 28 | 47 | 59.57% |
| 9 | 20 | 31 | 64.52% | 24 | 33 | 72.73% | 28 | 42 | 66.67% |
| 10 | 21 | 46 | 45.65% | 23 | 28 | 82.14% | 32 | 44 | 72.73% |
| 11 | 17 | 34 | 50.00% | 24 | 37 | 64.86% | 27 | 40 | 67.50% |
| 12 | 20 | 32 | 62.50% | 26 | 31 | 83.87% | 25 | 49 | 51.02% |
| 13 | 21 | 40 | 52.50% | 23 | 34 | 67.65% | 28 | 45 | 62.22% |
| 14 | 20 | 33 | 60.61% | 26 | 34 | 76.47% | 27 | 43 | 62.79% |
| 15 | 21 | 38 | 55.26% | 26 | 32 | 81.25% | 28 | 51 | 54.90% |
| 16 | 19 | 37 | 51.35% | 22 | 36 | 61.11% | 26 | 47 | 55.32% |
| 17 | 21 | 41 | 51.22% | 25 | 34 | 73.53% | 28 | 45 | 62.22% |
| 18 | 20 | 30 | 66.67% | 27 | 37 | 72.97% | 26 | 48 | 54.17% |
| 19 | 19 | 28 | 67.86% | 26 | 31 | 83.87% | 28 | 43 | 65.12% |
| 20 | 20 | 36 | 55.56% | 25 | 34 | 73.53% | 25 | 35 | 71.43% |
| 21 | 22 | 30 | 73.33% | 25 | 33 | 75.76% | 29 | 46 | 63.04% |
| 22 | 21 | 34 | 61.76% | 26 | 35 | 74.29% | 27 | 36 | 75.00% |
| 23 | 16 | 29 | 55.17% | 24 | 31 | 77.42% | 26 | 43 | 60.47% |
| 24 | 21 | 36 | 58.33% | 25 | 31 | 80.65% | 29 | 43 | 67.44% |
| 25 | 18 | 30 | 60.00% | 25 | 38 | 65.79% | 26 | 48 | 54.17% |
| Average | 20 | 34 | 58% | 25 | 32 | 77% | 28 | 46 | 61% |

| MOE 1 | MOE 2 - Survivability | | | | | |
|---|---|---|---|---|---|---|
| MOE 1 | HF Baseline | | CM Direct Fire | | CM Fire and Forget | |
| Run | Helicopters Killed | Average Kill Range | Helicopters Killed | Average Kill Range | Helicopters Killed | Average Kill Range |
| 1 | 1.000 | 4.320 | 1.000 | 3.590 | 1.000 | 2.671 |
| 2 | 5.000 | 3.435 | 1.000 | 3.590 | 1.000 | 3.590 |
| 3 | 1.000 | 4.839 | 1.000 | 3.590 | 1.000 | 2.949 |
| 4 | 3.000 | 4.053 | 0.000 | 0.000 | 1.000 | 3.590 |
| 5 | 2.000 | 3.585 | 0.000 | 0.000 | 1.000 | 3.590 |
| 6 | 3.000 | 4.129 | 1.000 | 3.590 | 1.000 | 3.590 |
| 7 | 2.000 | 4.030 | 1.000 | 3.590 | 1.000 | 3.590 |
| 8 | 0.000 | 0.000 | 2.000 | 4.061 | 1.000 | 3.590 |
| 9 | 1.000 | 3.251 | 1.000 | 3.590 | 0.000 | 0.000 |
| 10 | 1.000 | 4.847 | 1.000 | 3.590 | 0.000 | 0.000 |
| 11 | 2.000 | 4.795 | 1.000 | 3.590 | 1.000 | 3.590 |
| 12 | 4.000 | 3.356 | 1.000 | 3.590 | 0.000 | 0.000 |
| 13 | 1.000 | 4.845 | 2.000 | 4.061 | 1.000 | 3.590 |
| 14 | 1.000 | 3.158 | 1.000 | 2.671 | 0.000 | 0.000 |
| 15 | 0.000 | 0.000 | 1.000 | 3.590 | 1.000 | 4.533 |
| 16 | 0.000 | 0.000 | 2.000 | 4.061 | 1.000 | 3.590 |
| 17 | 3.000 | 3.755 | 1.000 | 3.590 | 1.000 | 3.590 |
| 18 | 1.000 | 4.560 | 1.000 | 3.590 | 1.000 | 3.590 |
| 19 | 4.000 | 3.652 | 1.000 | 3.590 | 1.000 | 3.590 |
| 20 | 1.000 | 4.890 | 1.000 | 3.590 | 1.000 | 3.590 |
| 21 | 3.000 | 3.446 | 1.000 | 3.590 | 0.000 | 0.000 |
| 22 | 2.000 | 3.991 | 1.000 | 3.590 | 0.000 | 0.000 |
| 23 | 2.000 | 3.174 | 1.000 | 3.590 | 1.000 | 3.590 |
| 24 | 1.000 | 3.205 | 1.000 | 4.630 | 0.000 | 0.000 |
| 25 | 4.000 | 4.157 | 1.000 | 3.590 | 1.000 | 3.590 |
| Average | 1.920 | 3.499 | 1.040 | 3.364 | 0.720 | 2.560 |

| MOE 3 | MOE 3 - Engagement | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| MOE 3 | Hellfire Base Case | | | CM Direct Fire | | | CM Fire and Forget | | |
| Run | Min Kill Range | Avg Kill Range | Max Kill Range | Min Kill Range | Avg Kill Range | Max Kill Range | Min Kill Range | Avg Kill Range | Max Kill Range |
| 1 | 4.019 | 6.438 | 7.938 | 6.866 | 11.276 | 11.944 | 3.81 | 8.993 | 11.95 |
| 2 | 3.485 | 6.527 | 7.969 | 7.232 | 9.496 | 11.949 | 4.37 | 8.914 | 11.989 |
| 3 | 3.45 | 6.784 | 7.997 | 6.386 | 9.382 | 11.983 | 4.05 | 8.22 | 12.4 |
| 4 | 2.52 | 5.229 | 7.964 | 6.717 | 9.188 | 11.983 | 4.53 | 8.975 | 11.949 |
| 5 | 3.832 | 6.086 | 7.953 | 6.717 | 9.188 | 11.983 | 4.77 | 10.168 | 11.949 |
| 6 | 2.97 | 6.752 | 7.998 | 6.436 | 9.212 | 11.564 | 4.53 | 8.451 | 11.883 |
| 7 | 1.571 | 6.316 | 7.987 | 5.679 | 9.42 | 11.936 | 4.81 | 8.213 | 11.966 |
| 8 | 3.277 | 6.785 | 7.97 | 6.272 | 9.042 | 11.956 | 5.04 | 8.285 | 11.944 |
| 9 | 2.815 | 7.338 | 7.969 | 6.339 | 9.19 | 11.945 | 5.04 | 8.8 | 11.949 |
| 10 | 3.972 | 6.592 | 8.108 | 4.7 | 9.265 | 11.983 | 4.77 | 8.472 | 11.97 |
| 11 | 3.575 | 6.55 | 7.997 | 6.147 | 8.832 | 11.933 | 5.04 | 9.226 | 11.933 |
| 12 | 4.69 | 6.712 | 7.982 | 6.055 | 9.472 | 11.949 | 3.98 | 8.615 | 11.586 |
| 13 | 3.471 | 6.586 | 7.948 | 5.947 | 9.192 | 11.911 | 4.77 | 8.5 | 11.983 |
| 14 | 3.158 | 6.341 | 7.997 | 3.709 | 8.802 | 11.97 | 4.674 | 8.312 | 11.933 |
| 15 | 2.126 | 6.066 | 7.918 | 4.506 | 9.664 | 11.949 | 4.53 | 8.873 | 11.938 |
| 16 | 3.325 | 6.369 | 7.995 | 6.391 | 9.405 | 11.911 | 4.8 | 8.607 | 11.945 |
| 17 | 3.064 | 6.637 | 7.999 | 5.565 | 9.325 | 11.983 | 4.8 | 8.566 | 11.945 |
| 18 | 4.363 | 6.59 | 7.951 | 6.118 | 9.184 | 11.983 | 4.77 | 9.224 | 11.949 |
| 19 | 3.925 | 6.537 | 7.982 | 6.819 | 9.632 | 11.949 | 4.85 | 8.974 | 11.914 |
| 20 | 2.028 | 6.492 | 7.951 | 4.915 | 9.196 | 11.954 | 4.53 | 8.715 | 11.922 |
| 21 | 1.747 | 6.34 | 7.977 | 5.376 | 9.08 | 11.949 | 4.81 | 9.105 | 11.98 |
| 22 | 1.851 | 6.208 | 7.997 | 4.3 | 8.63 | 11.911 | 4.524 | 8.285 | 11.909 |
| 23 | 3.1 | 6.08 | 7.852 | 6.436 | 9.238 | 11.787 | 4.74 | 9.614 | 11.933 |
| 24 | 2.91 | 6.357 | 7.906 | 5.36 | 9.051 | 11.922 | 4.8 | 9.283 | 11.949 |
| 25 | 4.411 | 6.34 | 7.97 | 6.436 | 9.458 | 11.949 | 4.655 | 7.838 | 11.944 |
| Average | 3.186 | 6.442 | 7.971 | 5.897 | 9.313 | 11.929 | 4.640 | 8.769 | 11.948 |

## B. RAW DATA

### 1. Scenario 245 (HF Baseline)

| Run | | Kills | Avg KR | Max KR | Min KR | Shots | Wt. Avg KR | AVG KR |
|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | |
| | BM-21 | 11 | 6.024 | 7.911 | 4.019 | 13 | 66.264 | |
| | T72 | 7 | 6.468 | 7.919 | 4.799 | 8 | 45.276 | |
| | ZSU-23-4 | 4 | 7.525 | 7.938 | 7.013 | 5 | 30.1 | |
| 2 | | 22 | | 7.938 | 4.019 | 26 | | 6.438 |
| | BM-21 | 7 | 5.977 | 7.906 | 4.402 | 17 | 41.839 | |
| | T72 | 7 | 7.151 | 7.969 | 4.802 | 9 | 50.057 | |
| | ZSU-23-4 | 4 | 6.397 | 7.951 | 3.485 | 10 | 25.588 | |
| 3 | | 18 | | 7.969 | 3.485 | 36 | | 6.527 |
| | BM-21 | 8 | 7.364 | 7.997 | 4.628 | 16 | 58.912 | |
| | T72 | 8 | 5.867 | 7.96 | 3.45 | 13 | 46.936 | |
| | ZSU-23-4 | 4 | 7.459 | 7.951 | 7.095 | 5 | 29.836 | |
| 4 | | 20 | | 7.997 | 3.45 | 34 | | 6.784 |
| | BM-21 | 7 | 6.375 | 7.964 | 2.52 | 9 | 44.625 | |
| | T72 | 6 | 6.675 | 7.946 | 3.312 | 11 | 19.872 | |
| | ZSU-23-4 | 4 | 6.099 | 7.23 | 4.85 | 10 | 24.396 | |
| 5 | | 17 | | 7.964 | 2.52 | 30 | | 5.229 |
| | BM-21 | 9 | 5.614 | 7.953 | 3.832 | 19 | 50.526 | |
| | T72 | 4 | 6.305 | 7.526 | 4.835 | 12 | 25.22 | |
| | ZSU-23-4 | 4 | 6.929 | 7.897 | 4.815 | 10 | 27.716 | |
| 6 | | 17 | | 7.953 | 3.832 | 41 | | 6.086 |
| | BM-21 | 9 | 6.759 | 7.997 | 4.365 | 14 | 60.831 | |
| | T72 | 6 | 6.359 | 7.998 | 2.97 | 15 | 38.154 | |
| | ZSU-23-4 | 4 | 7.326 | 7.951 | 6.766 | 5 | 29.304 | |
| 7 | | 19 | | 7.998 | 2.97 | 34 | | 6.752 |
| | BM-21 | 5 | 6.741 | 7.987 | 4.705 | 13 | 33.705 | |
| | T72 | 5 | 5.373 | 7.982 | 1.571 | 10 | 26.865 | |
| | ZSU-23-4 | 4 | 6.963 | 7.951 | 5.884 | 6 | 27.852 | |
| 8 | | 14 | | 7.987 | 1.571 | 29 | | 6.316 |
| | BM-21 | 12 | 6.631 | 7.948 | 3.277 | 22 | 79.572 | |
| | T72 | 8 | 6.981 | 7.97 | 5.065 | 12 | 55.848 | |
| | ZSU-23-4 | 4 | 6.854 | 7.193 | 6.434 | 5 | 27.416 | |
| 9 | | 24 | | 7.97 | 3.277 | 39 | | 6.785 |
| | BM-21 | 10 | 6.57 | 7.945 | 4.628 | 14 | 79.45 | |
| | T72 | 6 | 6.252 | 7.969 | 2.815 | 12 | 37.512 | |
| | ZSU-23-4 | 4 | 7.447 | 7.906 | 7.193 | 5 | 29.788 | |
| 10 | | 20 | | 7.969 | 2.815 | 31 | | 7.338 |
| | BM-21 | 10 | 6.51 | 8.108 | 3.972 | 18 | 65.1 | |
| | T72 | 7 | 6.352 | 7.605 | 4.356 | 22 | 44.464 | |
| | ZSU-23-4 | 4 | 7.215 | 7.343 | 7.045 | 6 | 28.86 | |
| 11 | | 21 | | 8.108 | 3.972 | 46 | | 6.592 |
| | BM-21 | 8 | 6.216 | 7.997 | 3.575 | 15 | 49.728 | |
| | T72 | 5 | 6.377 | 7.926 | 5.039 | 10 | 31.885 | |
| | ZSU-23-4 | 4 | 7.433 | 7.993 | 7.455 | 9 | 29.732 | |
| 12 | | 17 | | 7.997 | 3.575 | 34 | | 6.550 |
| | BM-21 | 9 | 6.461 | 7.765 | 4.69 | 15 | 58.149 | |
| | T72 | 7 | 6.597 | 7.982 | 4.854 | 11 | 46.179 | |
| | ZSU-23-4 | 4 | 7.477 | 7.922 | 7.199 | 6 | 29.908 | |
| | | 20 | | 7.982 | 4.69 | 32 | | 6.712 |

The fourth column under each run represents the total, max, min, or average of that run.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 13 | | | | | | | | |
| | BM-21 | 9 | 6.744 | 7.948 | 4.537 | 14 | 60.696 | |
| | T72 | 8 | 6.492 | 7.883 | 3.471 | 13 | 51.936 | |
| | ZSU-23-4 | 4 | 6.417 | 7.714 | 4.429 | 13 | 25.668 | |
| 14 | | 21 | | 7.948 | 3.471 | 40 | | 6.586 |
| | BM-21 | 10 | 6.313 | 7.997 | 3.785 | 16 | 63.13 | |
| | T72 | 6 | 5.674 | 7.878 | 3.158 | 11 | 34.044 | |
| | ZSU-23-4 | 4 | 7.413 | 7.951 | 6.438 | 6 | 29.652 | |
| 15 | | 20 | | 7.997 | 3.158 | 33 | | 6.341 |
| | BM-21 | 11 | 5.726 | 7.918 | 2.126 | 19 | 62.986 | |
| | T72 | 6 | 6.151 | 7.55 | 4.633 | 13 | 36.906 | |
| | ZSU-23-4 | 4 | 6.875 | 7.747 | 5.934 | 6 | 27.5 | |
| 16 | | 21 | | 7.918 | 2.126 | 38 | | 6.066 |
| | BM-21 | 8 | 6.79 | 7.995 | 4.393 | 14 | 54.32 | |
| | T72 | 7 | 5.883 | 7.535 | 3.325 | 10 | 41.181 | |
| | ZSU-23-4 | 4 | 6.377 | 7.364 | 4.474 | 13 | 25.508 | |
| 17 | | 19 | | 7.995 | 3.325 | 37 | | 6.369 |
| | BM-21 | 9 | 6.773 | 7.999 | 4.507 | 17 | 60.957 | |
| | T72 | 8 | 6.156 | 7.919 | 3.064 | 19 | 49.248 | |
| | ZSU-23-4 | 4 | 7.291 | 7.951 | 6.629 | 5 | 29.164 | |
| 18 | | 21 | | 7.999 | 3.064 | 41 | | 6.637 |
| | BM-21 | 10 | 6.464 | 7.936 | 4.363 | 13 | 64.64 | |
| | T72 | 6 | 6.255 | 7.111 | 4.563 | 8 | 37.53 | |
| | ZSU-23-4 | 4 | 7.408 | 7.951 | 7.095 | 9 | 29.632 | |
| 19 | | 20 | | 7.951 | 4.363 | 30 | | 6.590 |
| | BM-21 | 11 | 6.562 | 7.982 | 3.925 | 14 | 72.182 | |
| | T72 | 4 | 5.898 | 7.674 | 4.953 | 8 | 23.592 | |
| | ZSU-23-4 | 4 | 7.105 | 7.938 | 5.91 | 6 | 28.42 | |
| 20 | | 19 | | 7.982 | 3.925 | 28 | | 6.537 |
| | BM-21 | 9 | 5.638 | 7.718 | 2.028 | 19 | 50.742 | |
| | T72 | 7 | 7.08 | 7.889 | 5.207 | 11 | 49.56 | |
| | ZSU-23-4 | 4 | 7.384 | 7.951 | 6.583 | 6 | 29.536 | |
| 21 | | 20 | | 7.951 | 2.028 | 36 | | 6.492 |
| | BM-21 | 12 | 6.588 | 7.977 | 2.564 | 14 | 79.056 | |
| | T72 | 6 | 5.259 | 7.408 | 1.747 | 10 | 31.554 | |
| | ZSU-23-4 | 4 | 7.22 | 7.951 | 6.438 | 6 | 28.88 | |
| 22 | | 22 | | 7.977 | 1.747 | 30 | | 6.340 |
| | BM-21 | 10 | 6.239 | 7.997 | 2.52 | 15 | 62.39 | |
| | T72 | 7 | 5.559 | 7.926 | 1.851 | 14 | 38.913 | |
| | ZSU-23-4 | 4 | 7.265 | 7.993 | 6.453 | 5 | 29.06 | |
| 23 | | 21 | | 7.997 | 1.851 | 34 | | 6.208 |
| | BM-21 | 6 | 5.902 | 7.773 | 4.411 | 13 | 35.412 | |
| | T72 | 6 | 5.532 | 7.714 | 3.1 | 10 | 33.192 | |
| | ZSU-23-4 | 4 | 7.169 | 7.852 | 6.612 | 6 | 28.676 | |
| 24 | | 16 | | 7.852 | 3.1 | 29 | | 6.080 |
| | BM-21 | 11 | 6.124 | 7.745 | 3.356 | 18 | 67.364 | |
| | T72 | 6 | 6.184 | 7.824 | 2.91 | 13 | 37.104 | |
| | ZSU-23-4 | 4 | 7.259 | 7.906 | 6.433 | 5 | 29.036 | |
| 25 | | 21 | | 7.906 | 2.91 | 36 | | 6.357 |
| | BM-21 | 9 | 6.33 | 7.952 | 4.411 | 17 | 56.97 | |
| | T72 | 5 | 6.286 | 7.97 | 4.519 | 6 | 31.43 | |
| | ZSU-23-4 | 4 | 6.431 | 7.922 | 4.678 | 7 | 25.724 | |
| | | 18 | | 7.97 | 4.411 | 30 | | 6.340 |

## 2. Scenario 255 (CM Direct Fire)

| Run | | Kills | Avg KR | Max KR | Min KR | Shots | Wt. Avg KR | AVG KR |
|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | |
| | BM-21 | 13 | 9.783 | 11.944 | 6.866 | 20 | 155.272 | |
| | T72 | 6 | 8.251 | 9.427 | 7.033 | 6 | 56.562 | |
| | ZSU-23-4 | 4 | 10.005 | 11.88 | 7.918 | 5 | 47.52 | |
| 2 | | 23 | | 11.944 | 6.866 | 31 | | 11.276 |
| | BM-21 | 14 | 9.129 | 11.933 | 7.232 | 21 | 127.806 | |
| | T72 | 7 | 10.067 | 11.949 | 7.931 | 9 | 70.469 | |
| | ZSU-23-4 | 4 | 9.781 | 10.96 | 8.338 | 4 | 39.124 | |
| 3 | | 25 | | 11.949 | 7.232 | 34 | | 9.496 |
| | BM-21 | 14 | 9.555 | 11.983 | 6.386 | 17 | 133.77 | |
| | T72 | 8 | 8.633 | 11.98 | 6.84 | 9 | 69.064 | |
| | ZSU-23-4 | 4 | 10.274 | 11.564 | 8.54 | 4 | 41.096 | |
| 4 | | 26 | | 11.983 | 6.386 | 30 | | 9.382 |
| | BM-21 | 13 | 9.418 | 11.983 | 6.909 | 18 | 122.434 | |
| | T72 | 7 | 8.368 | 9.498 | 6.717 | 7 | 58.576 | |
| | ZSU-23-4 | 4 | 9.878 | 11.789 | 7.804 | 4 | 39.512 | |
| 5 | | 24 | | 11.983 | 6.717 | 29 | | 9.188 |
| | BM-21 | 13 | 9.418 | 11.983 | 6.909 | 18 | 122.434 | |
| | T72 | 7 | 8.368 | 9.085 | 6.717 | 7 | 58.576 | |
| | ZSU-23-4 | 4 | 9.878 | 11.789 | 7.804 | 4 | 39.512 | |
| 6 | | 24 | | 11.983 | 6.717 | 29 | | 9.188 |
| | BM-21 | 14 | 9.239 | 11.128 | 6.436 | 18 | 129.346 | |
| | T72 | 7 | 8.638 | 11.514 | 6.834 | 7 | 60.466 | |
| | ZSU-23-4 | 4 | 10.125 | 11.564 | 8.606 | 4 | 40.5 | |
| 7 | | 25 | | 11.564 | 6.436 | 29 | | 9.212 |
| | BM-21 | 15 | 9.741 | 11.936 | 6.536 | 18 | 146.115 | |
| | T72 | 6 | 8.623 | 11.83 | 5.679 | 8 | 51.738 | |
| | ZSU-23-4 | 4 | 9.409 | 11.329 | 7.594 | 5 | 37.636 | |
| 8 | | 25 | | 11.936 | 5.679 | 31 | | 9.420 |
| | BM-21 | 13 | 9.364 | 11.956 | 6.272 | 17 | 121.732 | |
| | T72 | 5 | 8.73 | 9.47 | 7.606 | 5 | 43.65 | |
| | ZSU-23-4 | 4 | 8.384 | 10.789 | 6.921 | 5 | 33.536 | |
| 9 | | 22 | | 11.956 | 6.272 | 27 | | 9.042 |
| | BM-21 | 12 | 9.453 | 11.945 | 6.339 | 17 | 113.436 | |
| | T72 | 8 | 8.927 | 11.752 | 6.943 | 9 | 71.416 | |
| | ZSU-23-4 | 4 | 8.925 | 11.69 | 7.153 | 7 | 35.7 | |
| 10 | | 24 | | 11.945 | 6.339 | 33 | | 9.190 |
| | BM-21 | 14 | 9.205 | 11.983 | 4.7 | 17 | 128.87 | |
| | T72 | 5 | 8.648 | 10.989 | 6.428 | 7 | 43.24 | |
| | ZSU-23-4 | 4 | 10.247 | 11.88 | 8.606 | 4 | 40.988 | |
| 11 | | 23 | | 11.983 | 4.7 | 28 | | 9.265 |
| | BM-21 | 12 | 8.943 | 11.933 | 7.024 | 20 | 107.316 | |
| | T72 | 8 | 8.721 | 11.203 | 7.034 | 12 | 69.768 | |
| | ZSU-23-4 | 4 | 8.719 | 10.96 | 6.147 | 5 | 34.876 | |
| 12 | | 24 | | 11.933 | 6.147 | 37 | | 8.832 |
| | BM-21 | 14 | 9.764 | 11.949 | 6.286 | 18 | 136.696 | |
| | T72 | 8 | 9.437 | 11.681 | 8.132 | 9 | 75.496 | |
| | ZSU-23-4 | 4 | 8.521 | 11.88 | 6.055 | 4 | 34.084 | |
| | | 26 | | 11.949 | 6.055 | 31 | | 9.472 |

The fourth column under each run represents the total, max, min, or average of that run.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 13 | | | | | | | | |
| | BM-21 | 13 | 9.597 | 11.911 | 7.203 | 19 | 124.761 | |
| | T72 | 6 | 9.64 | 11.082 | 8.13 | 7 | 57.84 | |
| | ZSU-23-4 | 4 | 7.204 | 8.313 | 5.947 | 8 | 28.816 | |
| 14 | | 23 | | 11.911 | 5.947 | 34 | | 9.192 |
| | BM-21 | 15 | 9.101 | 11.97 | 5.804 | 18 | 136.515 | |
| | T72 | 7 | 8.598 | 11.924 | 3.709 | 8 | 60.186 | |
| | ZSU-23-4 | 4 | 8.036 | 10.882 | 5.513 | 8 | 32.144 | |
| 15 | | 26 | | 11.97 | 3.709 | 34 | | 8.802 |
| | BM-21 | 14 | 9.397 | 11.944 | 4.506 | 19 | 131.558 | |
| | T72 | 8 | 9.815 | 11.949 | 7.606 | 8 | 78.52 | |
| | ZSU-23-4 | 4 | 10.295 | 11.255 | 9.331 | 5 | 41.18 | |
| 16 | | 26 | | 11.949 | 4.506 | 32 | | 9.664 |
| | BM-21 | 13 | 10.243 | 11.911 | 7.27 | 21 | 133.159 | |
| | T72 | 5 | 7.743 | 9.169 | 6.946 | 9 | 38.715 | |
| | ZSU-23-4 | 4 | 8.758 | 10.899 | 6.391 | 6 | 35.032 | |
| 17 | | 22 | | 11.911 | 6.391 | 36 | | 9.405 |
| | BM-21 | 14 | 9.544 | 11.983 | 5.565 | 20 | 133.616 | |
| | T72 | 7 | 8.739 | 11.481 | 6.931 | 8 | 61.173 | |
| | ZSU-23-4 | 4 | 9.582 | 11.247 | 7.906 | 6 | 38.328 | |
| 18 | | 25 | | 11.983 | 5.565 | 34 | | 9.325 |
| | BM-21 | 15 | 9.213 | 11.983 | 6.118 | 20 | 138.195 | |
| | T72 | 8 | 8.931 | 11.481 | 6.911 | 11 | 71.448 | |
| | ZSU-23-4 | 4 | 9.582 | 11.247 | 7.906 | 6 | 38.328 | |
| 19 | | 27 | | 11.983 | 6.118 | 37 | | 9.184 |
| | BM-21 | 14 | 9.392 | 11.949 | 7.307 | 16 | 131.488 | |
| | T72 | 8 | 9.825 | 11.938 | 6.819 | 11 | 78.6 | |
| | ZSU-23-4 | 4 | 10.085 | 11.614 | 7.906 | 4 | 40.34 | |
| 20 | | 26 | | 11.949 | 6.819 | 31 | | 9.632 |
| | BM-21 | 13 | 9.303 | 11.954 | 5.009 | 17 | 120.939 | |
| | T72 | 8 | 8.559 | 9.886 | 4.915 | 10 | 68.472 | |
| | ZSU-23-4 | 4 | 10.122 | 11.789 | 8.436 | 7 | 40.488 | |
| 21 | | 25 | | 11.954 | 4.915 | 34 | | 9.196 |
| | BM-21 | 14 | 9.384 | 11.949 | 6.336 | 19 | 131.376 | |
| | T72 | 7 | 9.176 | 10.629 | 6.944 | 8 | 64.232 | |
| | ZSU-23-4 | 4 | 7.849 | 10.504 | 5.376 | 6 | 31.396 | |
| 22 | | 25 | | 11.949 | 5.376 | 33 | | 9.080 |
| | BM-21 | 14 | 8.926 | 11.911 | 7.14 | 18 | 124.964 | |
| | T72 | 8 | 8.332 | 11.488 | 4.3 | 12 | 66.656 | |
| | ZSU-23-4 | 4 | 8.19 | 11.292 | 6.89 | 5 | 32.76 | |
| 23 | | 26 | | 11.911 | 4.3 | 35 | | 8.630 |
| | BM-21 | 14 | 9.429 | 11.787 | 6.436 | 19 | 132.006 | |
| | T72 | 6 | 8.288 | 10.883 | 7.165 | 8 | 49.728 | |
| | ZSU-23-4 | 4 | 9.996 | 10.966 | 9.43 | 4 | 39.984 | |
| 24 | | 24 | | 11.787 | 6.436 | 31 | | 9.238 |
| | BM-21 | 14 | 8.932 | 11.922 | 5.36 | 19 | 125.048 | |
| | T72 | 7 | 8.922 | 10.03 | 7.807 | 8 | 62.454 | |
| | ZSU-23-4 | 4 | 9.693 | 11.547 | 7.556 | 4 | 38.772 | |
| 25 | | 25 | | 11.922 | 5.36 | 31 | | 9.051 |
| | BM-21 | 15 | 9.503 | 11.899 | 6.436 | 23 | 142.545 | |
| | T72 | 6 | 9.14 | 11.949 | 7.47 | 9 | 54.84 | |
| | ZSU-23-4 | 4 | 9.769 | 11.88 | 7.523 | 6 | 39.076 | |
| | | 25 | | 11.949 | 6.436 | 38 | | 9.458 |

## 3. Scenario 235 (CM Fire-and-Forget)

The fourth column under each run represents the total, max, min, or average of that run.

| Run | | Kills | Avg KR | Max KR | Min KR | Shots | Wt. Avg KR | AVG KR |
|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | |
| | BM-21 | 9 | 10.092 | 11.945 | 7.038 | 15 | 90.828 | |
| | T72 | 5 | 8.835 | 11.488 | 5.984 | 7 | 44.175 | |
| | ZSU-23-4 | 4 | 10.047 | 11.352 | 8.606 | 4 | 40.188 | |
| | ICM | 10 | 7.66 | 11.95 | 3.81 | 25 | 76.6 | |
| 2 | | 28 | | 11.95 | 3.81 | 51 | | 8.993 |
| | BM-21 | 13 | 9.792 | 11.989 | 6.536 | 15 | 127.296 | |
| | T72 | 5 | 8.835 | 11.488 | 5.984 | 7 | 44.175 | |
| | ZSU-23-4 | 4 | 10.047 | 11.352 | 8.606 | 4 | 40.188 | |
| | ICM | 8 | 6.97 | 9.79 | 4.37 | 18 | 55.76 | |
| 3 | | 30 | | 11.989 | 4.37 | 44 | | 8.914 |
| | BM-21 | 10 | 9.812 | 11.97 | 7.731 | 12 | 98.12 | |
| | T72 | 4 | 8.132 | 9.732 | 4.051 | 5 | 32.528 | |
| | ZSU-23-4 | 3 | 9.407 | 10.921 | 8.313 | 6 | 28.221 | |
| | ICM | 11 | 6.48 | 12.4 | 4.05 | 25 | 71.28 | |
| 4 | | 28 | | 12.4 | 4.05 | 48 | | 8.220 |
| | BM-21 | 12 | 9.753 | 11.911 | 7.242 | 20 | 117.036 | |
| | T72 | 3 | 9.876 | 11.949 | 8.08 | 4 | 29.628 | |
| | ZSU-23-4 | 3 | 8.453 | 9.085 | 7.96 | 4 | 25.359 | |
| | ICM | 9 | 7.81 | 11.23 | 4.53 | 28 | 70.29 | |
| 5 | | 27 | | 11.949 | 4.53 | 56 | | 8.975 |
| | BM-21 | 10 | 9.615 | 11.944 | 5.247 | 15 | 96.15 | |
| | T72 | 4 | 9.692 | 11.949 | 6.943 | 4 | 38.768 | |
| | ZSU-23-4 | 4 | 9.819 | 11.69 | 8.183 | 4 | 39.276 | |
| | ICM | 11 | 6.36 | 10.97 | 4.77 | 25 | 120.67 | |
| 6 | | 29 | | 11.949 | 4.77 | 48 | | 10.168 |
| | BM-21 | 13 | 8.995 | 11.883 | 6.286 | 15 | 116.935 | |
| | T72 | 5 | 9.022 | 11.488 | 7.322 | 7 | 45.11 | |
| | ZSU-23-4 | 4 | 8.489 | 10.504 | 5.93 | 5 | 33.956 | |
| | ICM | 6 | 6.77 | 10.76 | 4.53 | 18 | 40.62 | |
| 7 | | 28 | | 11.883 | 4.53 | 45 | | 8.451 |
| | BM-21 | 12 | 9.226 | 11.966 | 6.486 | 18 | 110.712 | |
| | T72 | 4 | 8.912 | 11.488 | 6.919 | 6 | 35.648 | |
| | ZSU-23-4 | 4 | 8.48 | 11.44 | 5.762 | 5 | 33.92 | |
| | ICM | 8 | 6.21 | 10.97 | 4.81 | 24 | 49.68 | |
| 8 | | 28 | | 11.966 | 4.81 | 53 | | 8.213 |
| | BM-21 | 12 | 8.914 | 11.944 | 6.025 | 18 | 106.968 | |
| | T72 | 6 | 8.181 | 11.432 | 5.67 | 6 | 49.086 | |
| | ZSU-23-4 | 4 | 9.996 | 11.696 | 8.323 | 5 | 39.984 | |
| | ICM | 6 | 5.99 | 6.89 | 5.04 | 18 | 35.94 | |
| 9 | | 28 | | 11.944 | 5.04 | 47 | | 8.285 |
| | BM-21 | 7 | 9.175 | 11.289 | 7.513 | 14 | 64.225 | |
| | T72 | 7 | 9.502 | 11.949 | 6.901 | 9 | 66.514 | |
| | ZSU-23-4 | 7 | 9.681 | 11.515 | 8.442 | 5 | 67.767 | |
| | ICM | 7 | 6.84 | 11.59 | 5.04 | 14 | 47.88 | |
| 10 | | 28 | | 11.949 | 5.04 | 42 | | 8.800 |
| | BM-21 | 8 | 9.61 | 11.97 | 7.485 | 14 | 76.88 | |
| | T72 | 8 | 7.877 | 11.083 | 6.335 | 7 | 63.016 | |
| | ZSU-23-4 | 8 | 10.171 | 11.88 | 8.338 | 4 | 81.368 | |
| | ICM | 8 | 6.23 | 8.27 | 4.77 | 19 | 49.84 | |
| 11 | | 32 | | 11.97 | 4.77 | 44 | | 8.472 |
| | BM-21 | 13 | 9.72 | 11.933 | 6.486 | 15 | 126.36 | |
| | T72 | 5 | 9.794 | 11.373 | 9.264 | 8 | 48.97 | |
| | ZSU-23-4 | 3 | 8.968 | 10.96 | 7.508 | 4 | 26.904 | |
| | ICM | 6 | 7.81 | 9.54 | 5.04 | 13 | 46.86 | |
| 12 | | 27 | | 11.933 | 5.04 | 40 | | 9.226 |
| | BM-21 | 11 | 9.461 | 11.586 | 6.218 | 18 | 104.071 | |
| | T72 | 3 | 8.104 | 9.482 | 7.225 | 7 | 24.312 | |
| | ZSU-23-4 | 4 | 10.091 | 11.449 | 9.37 | 5 | 40.364 | |
| | ICM | 7 | 6.66 | 9.65 | 3.98 | 19 | 46.62 | |
| | | 25 | | 11.586 | 3.98 | 49 | | 8.615 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 13 | | | | | | | | |
| | BM-21 | 11 | 9.665 | 11.983 | 7.526 | 14 | 106.315 | |
| | T72 | 5 | 9.384 | 11.914 | 6.927 | 6 | 46.92 | |
| | ZSU-23-4 | 2 | 8.431 | 9.085 | 7.778 | 3 | 16.862 | |
| | ICM | 10 | 6.79 | 11.59 | 4.77 | 22 | 67.9 | |
| 14 | | 28 | | 11.983 | 4.77 | 45 | | 8.500 |
| | BM-21 | 11 | 9.383 | 11.933 | 7.188 | 13 | 103.213 | |
| | T72 | 4 | 7.382 | 10.424 | 4.674 | 4 | 29.528 | |
| | ZSU-23-4 | 3 | 10.338 | 11.789 | 7.749 | 5 | 31.014 | |
| | ICM | 9 | 6.74 | 11.59 | 5.04 | 21 | 60.66 | |
| 15 | | 27 | | 11.933 | 4.674 | 43 | | 8.312 |
| | BM-21 | 13 | 9.328 | 11.899 | 6.517 | 15 | 121.264 | |
| | T72 | 4 | 9.403 | 11.938 | 7.98 | 4 | 37.612 | |
| | ZSU-23-4 | 4 | 10.175 | 11.547 | 9.233 | 5 | 40.7 | |
| | ICM | 7 | 6.98 | 11.68 | 4.53 | 27 | 48.86 | |
| 16 | | 28 | | 11.938 | 4.53 | 51 | | 8.873 |
| | BM-21 | 10 | 9.752 | 11.945 | 6.882 | 16 | 97.52 | |
| | T72 | 3 | 8.289 | 9.098 | 7.54 | 3 | 24.867 | |
| | ZSU-23-4 | 4 | 9.779 | 11.696 | 8.323 | 5 | 39.116 | |
| | ICM | 9 | 6.92 | 11.32 | 4.8 | 23 | 62.28 | |
| 17 | | 26 | | 11.945 | 4.8 | 47 | | 8.607 |
| | BM-21 | 7 | 9.822 | 11.945 | 7.053 | 11 | 68.754 | |
| | T72 | 6 | 10.717 | 11.914 | 6.985 | 6 | 64.302 | |
| | ZSU-23-4 | 3 | 7.396 | 8.183 | 6.132 | 5 | 22.188 | |
| | ICM | 12 | 7.05 | 10.67 | 4.8 | 23 | 84.6 | |
| 18 | | 28 | | 11.945 | 4.8 | 45 | | 8.566 |
| | BM-21 | 11 | 10.149 | 11.911 | 7.189 | 16 | 111.639 | |
| | T72 | 4 | 10.008 | 11.949 | 7.804 | 6 | 40.032 | |
| | ZSU-23-4 | 4 | 9.682 | 11.137 | 8.183 | 4 | 38.728 | |
| | ICM | 7 | 7.06 | 9.54 | 4.77 | 22 | 49.42 | |
| 19 | | 26 | | 11.949 | 4.77 | 48 | | 9.224 |
| | BM-21 | 11 | 9.056 | 11.914 | 6.336 | 15 | 99.616 | |
| | T72 | 7 | 9.049 | 11.88 | 6.87 | 8 | 63.343 | |
| | ZSU-23-4 | 4 | 9.779 | 11.564 | 7.701 | 4 | 39.116 | |
| | ICM | 6 | 8.2 | 11.79 | 4.85 | 16 | 49.2 | |
| 20 | | 28 | | 11.914 | 4.85 | 43 | | 8.974 |
| | BM-21 | 11 | 8.921 | 11.922 | 5.988 | 13 | 98.131 | |
| | T72 | 3 | 8.967 | 9.682 | 8.599 | 4 | 26.901 | |
| | ZSU-23-4 | 4 | 10.122 | 11.789 | 8.436 | 7 | 40.488 | |
| | ICM | 7 | 7.48 | 11.79 | 4.53 | 11 | 52.36 | |
| 21 | | 25 | | 11.922 | 4.53 | 35 | | 8.715 |
| | BM-21 | 13 | 10.048 | 11.945 | 7.267 | 19 | 130.624 | |
| | T72 | 4 | 9.976 | 11.98 | 7.712 | 4 | 39.904 | |
| | ZSU-23-4 | 4 | 9.917 | 11.564 | 7.872 | 5 | 39.668 | |
| | ICM | 8 | 6.73 | 11.68 | 4.81 | 18 | 53.84 | |
| 22 | | 29 | | 11.98 | 4.81 | 46 | | 9.105 |
| | BM-21 | 13 | 9.693 | 11.909 | 7.369 | 16 | 126.009 | |
| | T72 | 4 | 7.683 | 11.02 | 4.524 | 6 | 30.732 | |
| | ZSU-23-4 | 3 | 8.851 | 11.789 | 6.58 | 3 | 26.553 | |
| | ICM | 7 | 5.77 | 9.1 | 4.8 | 11 | 40.39 | |
| 23 | | 27 | | 11.909 | 4.524 | 36 | | 8.285 |
| | BM-21 | 11 | 9.252 | 11.933 | 6.336 | 13 | 101.772 | |
| | T72 | 6 | 9.747 | 11.488 | 7.221 | 8 | 58.482 | |
| | ZSU-23-4 | 4 | 10.138 | 11.613 | 8.183 | 4 | 40.552 | |
| | ICM | 5 | 9.83 | 11.59 | 4.74 | 18 | 49.15 | |
| 24 | | 26 | | 11.933 | 4.74 | 43 | | 9.614 |
| | BM-21 | 14 | 10.011 | 11.949 | 7.261 | 17 | 140.154 | |
| | T72 | 5 | 9.189 | 11.889 | 7.325 | 5 | 45.945 | |
| | ZSU-23-4 | 4 | 9.8 | 11.674 | 8.034 | 4 | 39.2 | |
| | ICM | 6 | 7.32 | 11.39 | 4.8 | 17 | 43.92 | |
| 25 | | 29 | | 11.949 | 4.8 | 43 | | 9.283 |
| | BM-21 | 9 | 9.648 | 11.944 | 6.909 | 16 | 86.832 | |
| | T72 | 4 | 8.166 | 11.481 | 4.655 | 6 | 32.664 | |
| | ZSU-23-4 | 3 | 9.629 | 11.247 | 8.308 | 4 | 28.887 | |
| | ICM | 10 | 5.54 | 6.89 | 4.77 | 22 | 55.4 | |
| | | 26 | | 11.944 | 4.655 | 48 | | 7.838 |

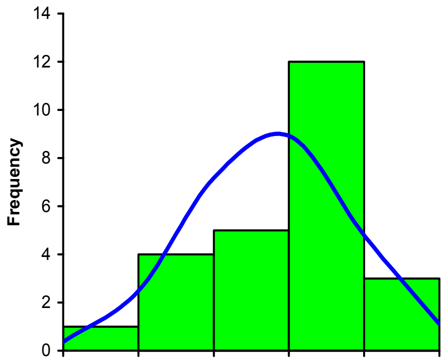
# APPENDIX C. MOE STATISTICAL SUMMARY DESCRIPTIVES

This appendix provides the summary descriptives of the statistics for each MOE independently. The data was analyzed and these reports produced by the Excel Analyze-it statistical add-in. A statistical summary descriptive is provided for each MOE by scenario. The scenarios are Hellfire Baseline (245), CM Direct Fire (255), and CM Fire-and-Forget (235).

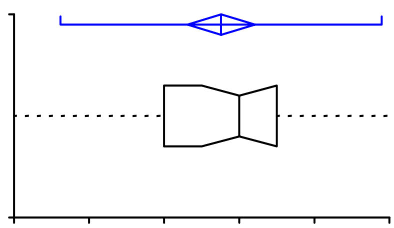
## A. SUMMARY STATISTICS MOE 1 – LETHALITY

analysed with: Analyse-it + General 1.62

| | |
|---|---|
| **Test** | **Continuous summary descriptives** |
| | MOE 1 - Lethality - HF Baseline - Kills |
| **Performed by** | Major John M. Vannoy |
| **Date** | 27 March 2002 |

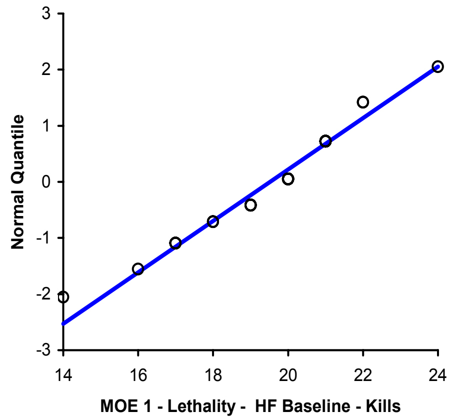



| | |
|---|---|
| **n** | 25 (cases excluded: 1 due to missing values) |
| **Mean** | 19.520 |
| **95% CI** | 18.619 to 20.421 |
| **Variance** | 4.7600 |
| **SD** | 2.1817 |
| **SE** | 0.4363 |
| **CV** | 11% |



| | |
|---|---|
| **Median** | 20.000 |
| **95.7% CI** | 19.000 to 21.000 |
| **Range** | 10 |
| **IQR** | 3 |

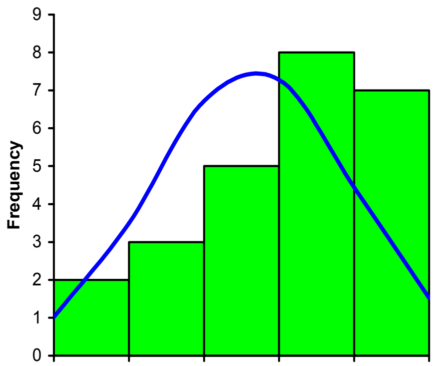
| **Percentile** | |
|---|---|
| **2.5th** | - |
| **25th** | 18.000 |
| **50th** | 20.000 |
| **75th** | 21.000 |
| **97.5th** | - |



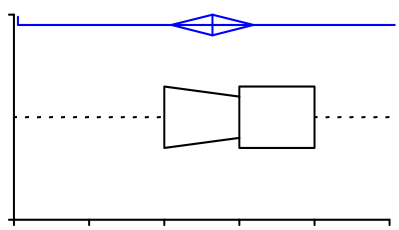

| | Coefficient | p |
|---|---|---|
| **Shapiro-Wilk** | 0.9522 | 0.2809 |
| **Skewness** | -0.5527 | 0.2189 |
| **Kurtosis** | 0.6515 | 0.3665 |

analysed with: Analyse-it + General 1.62

| | |
|---|---|
| **Test** | **Continuous summary descriptives** |
| | MOE 1 - Lethality - CM Direct Fire - Kills |
| **Performed by** | Major John M. Vannoy |
| **Date** | 27 March 2002 |

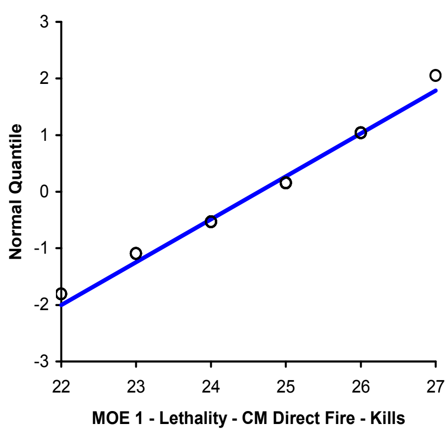



| | |
|---|---|
| **n** | 25 (cases excluded: 1 due to missing values) |
| **Mean** | 24.6 |
| **95% CI** | 24.1 to 25.2 |
| **Variance** | 1.74 |
| **SD** | 1.32 |
| **SE** | 0.26 |
| **CV** | 5% |



| | |
|---|---|
| **Median** | 25.0 |
| **95.7% CI** | 24.0 to 25.0 |
| **Range** | 5 |
| **IQR** | 2 |

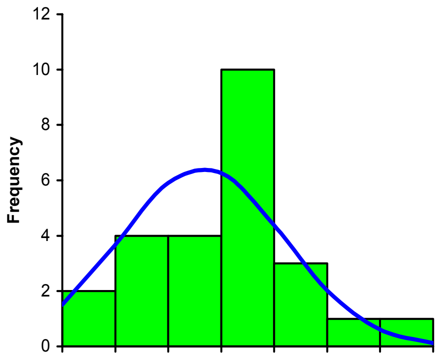
| Percentile | |
|---|---|
| **2.5th** | - |
| **25th** | 24.0 |
| **50th** | 25.0 |
| **75th** | 26.0 |
| **97.5th** | - |



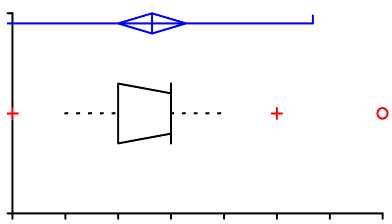

| | Coefficient | p |
|---|---|---|
| **Shapiro-Wilk** | 0.9272 | 0.0749 |
| **Skewness** | -0.4486 | 0.3135 |
| **Kurtosis** | -0.3854 | 0.7730 |

analysed with: Analyse-it + General 1.62

| | |
|---|---|
| **Test** | **Continuous summary descriptives** |
| | MOE 1 - Lethality - CM Fire and Forget - Kills |
| **Performed by** | Major John M. Vannoy |
| **Date** | 27 March 2002 |

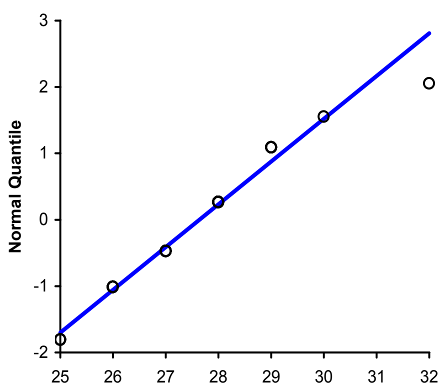



| | |
|---|---|
| **n** | 25 (cases excluded: 1 due to missing values) |
| **Mean** | 27.640 |
| **95% CI** | 27.000 to 28.280 |
| **Variance** | 2.4067 |
| **SD** | 1.5513 |
| **SE** | 0.3103 |
| **CV** | 6% |



| | |
|---|---|
| **Median** | 28.000 |
| **95.7% CI** | 27.000 to 28.000 |
| **Range** | 7 |
| **IQR** | 1 |

| **Percentile** | |
|---|---|
| **2.5th** | - |
| **25th** | 27.000 |
| **50th** | 28.000 |
| **75th** | 28.000 |
| **97.5th** | - |

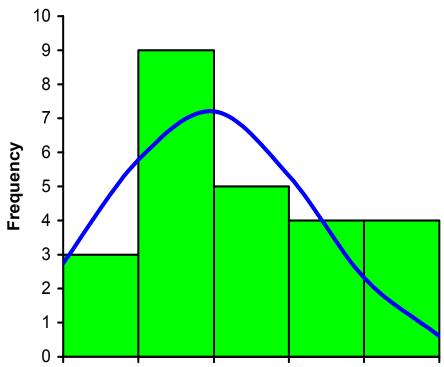



| | Coefficient | p |
|---|---|---|
| **Shapiro-Wilk** | 0.9197 | 0.0504 |
| **Skewness** | 0.5889 | 0.1918 |
| **Kurtosis** | 1.4788 | 0.1285 |

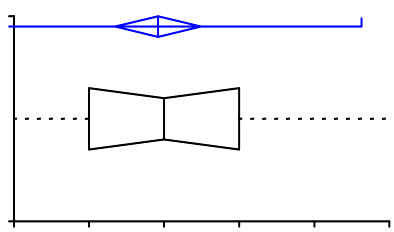
## B. SUMMARY STATISTICS MOE 2 – SURVIVABILITY

analysed with: Analyse-it + General 1.62

| | |
|---|---|
| **Test** | **Continuous summary descriptives** |
| | MOE 2 - Survivability - HF Baseline |
| **Performed by** | Major John M. Vannoy |
| **Date** | 27 March 2002 |

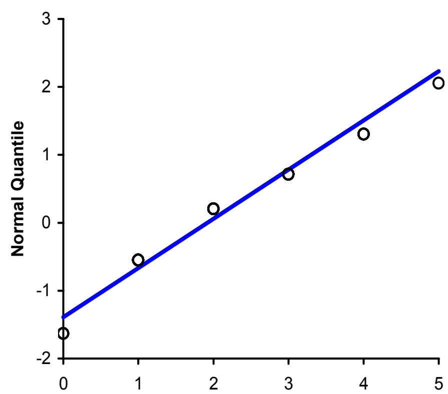



| | | |
|---|---|---|
| **n** | 25 | (cases excluded: 1 due to missing values) |
| **Mean** | 1.920 | |
| **95% CI** | 1.350 to 2.490 | |
| **Variance** | 1.9100 | |
| **SD** | 1.3820 | |
| **SE** | 0.2764 | |
| **CV** | 72% | |



| | |
|---|---|
| **Median** | 2.000 |
| **95.7% CI** | 1.000 to 3.000 |
| **Range** | 5 |
| **IQR** | 2 |

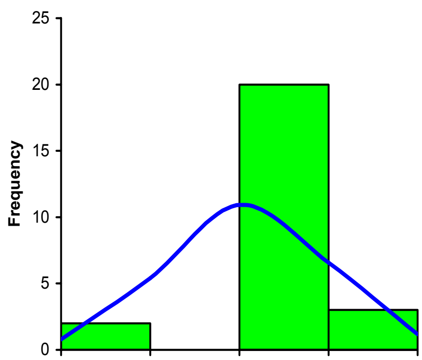
| **Percentile** | |
|---|---|
| **2.5th** | - |
| **25th** | 1.000 |
| **50th** | 2.000 |
| **75th** | 3.000 |
| **97.5th** | - |



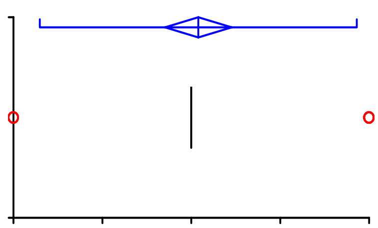

| | Coefficient | p |
|---|---|---|
| **Shapiro-Wilk** | 0.9103 | 0.0310 |
| **Skewness** | 0.5664 | 0.2082 |
| **Kurtosis** | -0.4982 | 0.6404 |

analysed with: Analyse-it + General 1.62

| | |
|---|---|
| **Test** | **Continuous summary descriptives** |
| | MOE 2 - Survivability - CM Direct Fire |
| **Performed by** | Major John M. Vannoy |
| **Date** | 27 March 2002 |

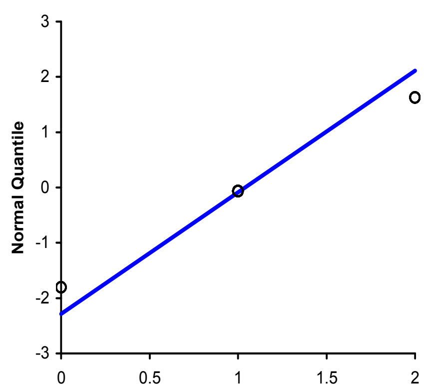



| | |
|---|---|
| **n** | 25 (cases excluded: 1 due to missing values) |
| **Mean** | 1.040 |
| **95% CI** | 0.852 to 1.228 |
| **Variance** | 0.2067 |
| **SD** | 0.4546 |
| **SE** | 0.0909 |
| **CV** | 44% |



| | |
|---|---|
| **Median** | 1.000 |
| **95.7% CI** | 1.000 to 1.000 |
| **Range** | 2 |
| **IQR** | 0 |

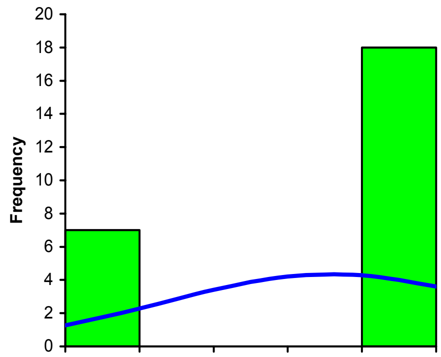
| **Percentile** | |
|---|---|
| **2.5th** | - |
| **25th** | 1.000 |
| **50th** | 1.000 |
| **75th** | 1.000 |
| **97.5th** | - |



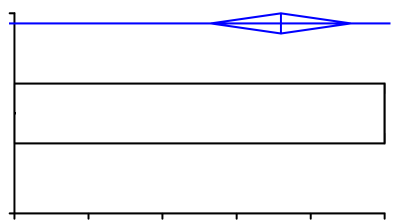

| | **Coefficient** | **p** |
|---|---|---|
| **Shapiro-Wilk** | 0.6243 | <0.0001 |
| **Skewness** | 0.1944 | 0.6572 |
| **Kurtosis** | 2.7102 | 0.0299 |

analysed with: Analyse-it + General 1.62

| | |
|---|---|
| **Test** | **Continuous summary descriptives** |
| | MOE 2 - Survivability - CM Fire and Forget |
| **Performed by** | Major John M. Vannoy |
| **Date** | 27 March 2002 |

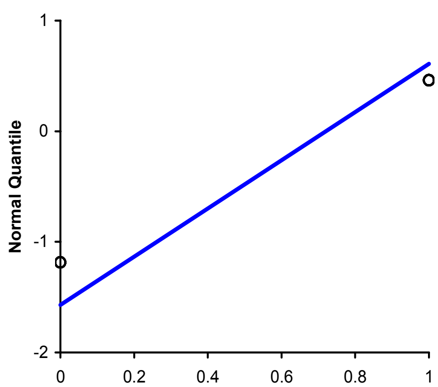



| | |
|---|---|
| **n** | 25 (cases excluded: 1 due to missing values) |
| **Mean** | 0.720 |
| **95% CI** | 0.531 to 0.909 |
| **Variance** | 0.2100 |
| **SD** | 0.4583 |
| **SE** | 0.0917 |
| **CV** | 64% |



| | |
|---|---|
| **Median** | 1.000 |
| **95.7% CI** | 1.000 to 1.000 |
| **Range** | 1 |
| **IQR** | 1 |

| **Percentile** | |
|---|---|
| **2.5th** | - |
| **25th** | 0.000 |
| **50th** | 1.000 |
| **75th** | 1.000 |
| **97.5th** | - |

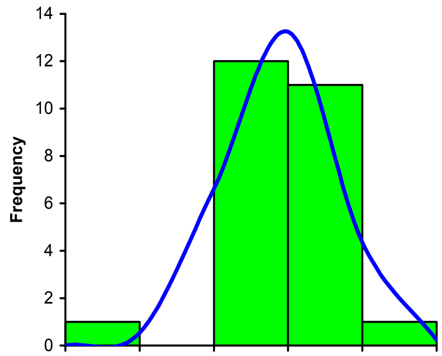



| | Coefficient | p |
|---|---|---|
| **Shapiro-Wilk** | 0.5650 | <0.0001 |
| **Skewness** | -1.0437 | 0.0293 |
| **Kurtosis** | -0.9976 | 0.1414 |

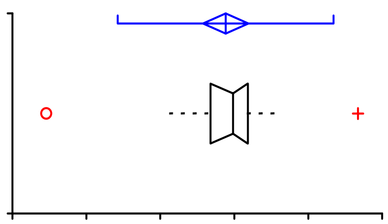
## C. SUMMARY STATISTICS MOE 3 – ENGAGEMENT

analysed with: Analyse-it + General 1.62

| | |
|---|---|
| **Test** | **Continuous summary descriptives** |
| | MOE 3 - Engagement - Hellfire Baseline |
| **Performed by** | Major John M. Vannoy |
| **Date** | 27 March 2002 |

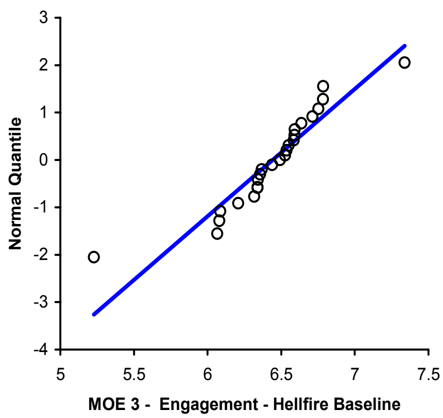



| | |
|---|---|
| **n** | 25 (cases excluded: 1 due to missing values) |
| **Mean** | 6.442 |
| **95% CI** | 6.288 to 6.596 |
| **Variance** | 0.1385 |
| **SD** | 0.3722 |
| **SE** | 0.0744 |
| **CV** | 6% |



| | |
|---|---|
| **Median** | 6.492 |
| **95.7% CI** | 6.340 to 6.590 |
| **Range** | 2.109 |
| **IQR** | 0.252 |

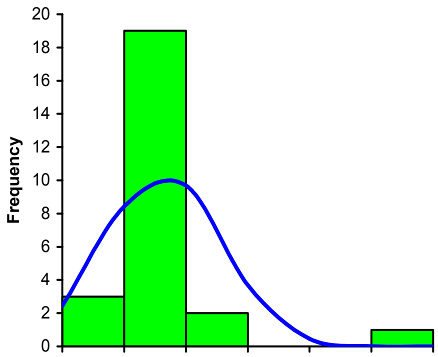
| **Percentile** | |
|---|---|
| **2.5th** | - |
| **25th** | 6.340 |
| **50th** | 6.492 |
| **75th** | 6.592 |
| **97.5th** | - |



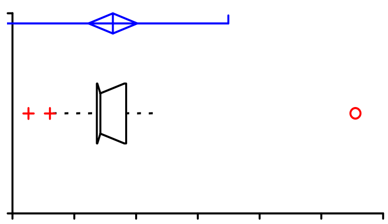

| | Coefficient | p |
|---|---|---|
| **Shapiro-Wilk** | 0.8881 | 0.0102 |
| **Skewness** | -0.9497 | 0.0443 |
| **Kurtosis** | 4.7064 | 0.0040 |

analysed with: Analyse-it + General 1.62

| | |
|---|---|
| **Test** | **Continuous summary descriptives** |
| | MOE 3 - Engagement - CM Direct Fire |
| **Performed by** | Major John M. Vannoy |
| **Date** | 27 March 2002 |

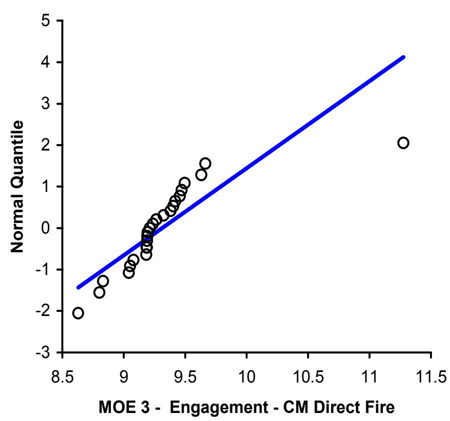



| | |
|---|---|
| **n** | 25 (cases excluded: 1 due to missing values) |
| **Mean** | 9.313 |
| **95% CI** | 9.116 to 9.509 |
| **Variance** | 0.2270 |
| **SD** | 0.4764 |
| **SE** | 0.0953 |
| **CV** | 5% |



| | |
|---|---|
| **Median** | 9.212 |
| **95.7% CI** | 9.188 to 9.405 |
| **Range** | 2.646 |
| **IQR** | 0.236 |

| **Percentile** | |
|---|---|
| **2.5th** | - |
| **25th** | 9.184 |
| **50th** | 9.212 |
| **75th** | 9.420 |
| **97.5th** | - |



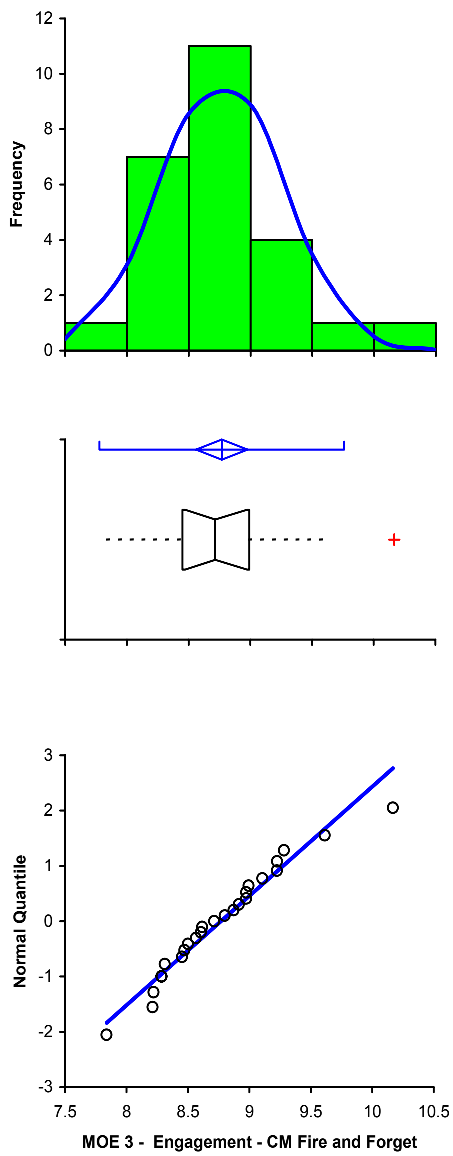

| | Coefficient | p |
|---|---|---|
| **Shapiro-Wilk** | 0.7012 | <0.0001 |
| **Skewness** | 2.9449 | <0.0001 |
| **Kurtosis** | 12.4123 | <0.0001 |

analysed with: Analyse-it + General 1.62

**Test** | **Continuous summary descriptives**

MOE 3 -  Engagement - CM Fire and Forget

**Performed by** | Major John M. Vannoy | **Date** | 27 March 2002



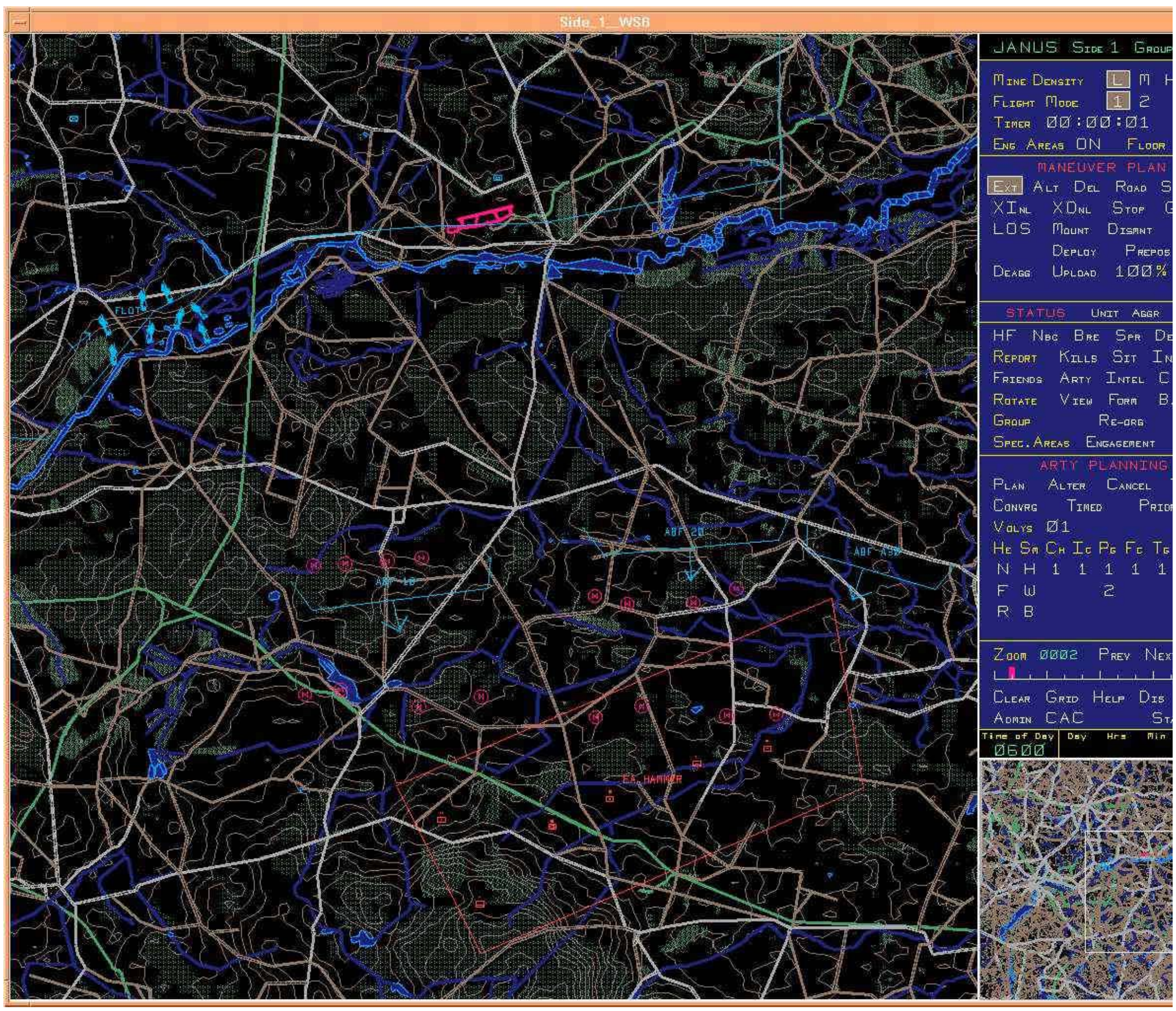

| | |
|---|---|
| **n** | 25 (cases excluded: 1 due to missing values) |
| **Mean** | 8.769 |
| **95% CI** | 8.560 to 8.978 |
| **Variance** | 0.2559 |
| **SD** | 0.5059 |
| **SE** | 0.1012 |
| **CV** | 6% |
| **Median** | 8.715 |
| **95.7% CI** | 8.472 to 8.975 |
| **Range** | 2.33 |
| **IQR** | 0.542 |

| **Percentile** | |
|---|---|
| **2.5th** | - |
| **25th** | 8.451 |
| **50th** | 8.715 |
| **75th** | 8.993 |
| **97.5th** | - |

| | Coefficient | p |
|---|---|---|
| **Shapiro-Wilk** | 0.9603 | 0.4210 |
| **Skewness** | 0.7607 | 0.0984 |
| **Kurtosis** | 1.1879 | 0.1852 |

# APPENDIX D. BATTLEFIELD GRAPHIC

This appendix provides a screen shot of the Janus terminal view of the battlefield for the deep attack scenario.



THIS PAGE INTENTIONALLY LEFT BLANK

# LIST OF REFERENCES


1. Department of Defense. Interim Regulation, DoD 5000.2-R. 4 January 2001.

2. PEO Tactical Missiles. "Common Missile (CM) – Analytical Support to Analysis of Alternatives." 3 August 2001.

3. PEO Tactical Missiles. "Missile Modernization Campaign Plan, General Officer Steering Committee #6." 3 May 2001.

4. PEO Tactical Missiles. "Common Missile Background and Description." https://peotm.redstone.army.mil/. 5 March 2001.

5. Common Missile Project Office. "Program Overview." 1 November 2001.

6. Keller, Sean P. "Simulation-Based Acquisition: Real-World Examples." RD&A Magazine. September-October 1998: 25-26.

7. Headquarters TRADOC. "Operational Requirements Document for the Joint Common Missile. Unclassified Version – Post Staffing." 12 March 2001.

8. Common Missile Project Office. "Information Paper on the Common Missile Program." 13 July 2001.

9. Pike, John. Military Analyst Network: AGM-114 Hellfire. April 2000. http://www.fas.org/man/dod-101/sys/missile/agm-114.htm.

10. Department of the Army. Janus Version 7.06D Documentation: Volume 1, TRADOC Analysis Center – White Sands Missile Range. July 2000. New Mexico.

11. Vannoy, John M. "AH-64D Longbow Apache Employment Information Paper." 10 March 2000.

12. Department of the Army. Field Manual 1-111 Aviation Brigades. 27 October 1997.

13. 21st Cavalry. "AH-64D Techniques, Tactics, and Procedures." 6 April 2000.

14. Vannoy, John M. "Instructional Briefing: Deep Attack." 2 August 1999.

15. Headquarters Department of the Army. Field Manual 100-61: Armor and Mechanized Based Opposing Force Operational Art. 26 January 1998.

16. Headquarters Department of the Army. Field Manual 100-60: Armor and Mechanized Based Opposing Force Organization Guide. 16 July 1997.

17. Eisenhard, Scot. Common Missile Program Office Contractor Analyst. Quality Research. Personal Meeting. 7 Dec 2001.

18. Perry, Robert. Common Missile Simulations Lead Engineer. Personal Meeting. 9 November 2001.

19. Smith, Marvin. Common Missile Contractor Analyst. Quality Research. 9 November 2001.

20. Hollis, Walter W., and Patenaude, Anne. "Simulation Based Acquisition: Can We Stay the Course?" Army RD&A, May-June 1999: 11-14.

21. Department of the Army, Army Model and Simulation Executive Council (AMSEC). "Planning Guidelines for Simulation and Modeling for Acquisition, Requirements, and Training (SMART)." September 15, 2000.

22. Pike, John. Military Analyst Network: AH-64 Apache. May 29, 2000. http://www.fas.org/man/dod-101/sys/ac/ah64.htm.

23. Pike, John. Military Analyst Network: T-72. January 16, 2000. http://www.fas.org/man/dod-101/sys/land/row/t72tank.htm.

24. Pike, John. Military Analyst Network: BM-21. June 19, 1999. http://www.fas.org/man/dod-101/sys/land/row/bm-21.htm.

25. Pike, John. Military Analyst Network: ZSU-23-4. January 22, 1999. http://www.fas.org/man/dod-101/sys/land/row/zsu-23-4.htm.

26. Analyze-it for Microsoft Excel Statistical Add-in Software Version 1.62. January 1, 2002.

27. Brusaw, Charles T., Alred, Gerald J., and Oliu, Walter E. Handbook of Technical Writing – Fifth Edition. New York: St. Martin's Press, Inc. 1997

THIS PAGE INTENTIONALLY LEFT BLANK

# INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
   Ft. Belvoir, VA

2. Dudley Knox Library
   Naval Postgraduate School
   Monterey, CA

3. Department of the Army
   Program Executive Office Aviation
   Redstone Arsenal, AL

4. Department of the Army
   Common Missile Program Office
   ATTN: Robert Perry
   Redstone Arsenal, AL

5. Department of the Army
   TRADOC System Manager Comanche
   Fort Rucker, AL

6. Department of the Army
   Comanche Program Office
   Redstone Arsenal, AL

7. Department of the Army
   Apache Program Office
   Redstone Arsenal, AL

8. Dr. Keith Snider
   Naval Postgraduate School
   Monterey, CA

9. Professor Bard Mansager
   Naval Postgraduate School
   Monterey, CA

10. CPT(P) Scott Crino
    TRAC - Monterey
    Monterey, CA

11. Dr. David Lamm
    Naval Postgraduate School
    Monterey, CA